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Atmospheric Disturbance Environment Definition

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ATMOSPHERIC DISTURBANCE ENVIRONMENT DEFINITION

1.0 Documentation Review

1.1 Background

Traditionally, the application of atmospheric disturbance data to airplane design problems has been the domain of the structures engineer. The primary concern in this case is the design of structural components sufficient to handle transient loads induced by the most severe atmospheric "gusts" that might be encountered. The concern has resulted in a considerable body of high altitude gust acceleration data obtained with VGH recorders (airplane velocity, V , vertical acceleration, G , altitude, H) on high-flying airplanes like the U-2 (Ehernberger and Love, 1975).

However, the propulsion system designer is less concerned with the accelerations of the airplane than he is with the airflow entering the system's inlet. When the airplane encounters atmospheric turbulence it responds with transient fluctuations in pitch, yaw, and roll angles. These transients, together with fluctuations in the free-stream temperature and pressure will disrupt the total pressure, temperature, Mach number and angularity of the inlet flow. For the mixed compression inlet, the result is a disturbed throat Mach number and/or shock position, and in extreme cases an inlet unstart can occur (cf. Section 2.1).

Interest in the effects of inlet unstart on the vehicle dynamics of large, supersonic airplanes is not new. Results published by NASA in 1962 of wind tunnel studies of the problem were used in support of the United States Supersonic Transport program (SST) (White, *et al*, 1963). Such studies continued into the late 1970's. However, in spite of such interest, there never was developed an atmospheric disturbance database for inlet unstart analysis to compare with that available for the structures load analysis. Missing were data for the free-stream temperature and pressure disturbances that also contribute to the unstart problem.

Consequently, an extensive literature search was conducted to confirm the types of data required for inlet unstart analysis; and to determine if updated databases for reliable analytical results have been produced in response to renewed interest in the unstart problem generated by the High Speed Research (HSR) program. The Appendix lists the bibliography of all references uncovered in this search. The listings are categorized according to the main focus of each reference (e.g., theory, experiment, data, etc.). However, many references could be included under several categories. The Appendix does not include such cross-referencing. Key references to material in the body of this report are in the separate list of text references.

1.2 Disturbance Databases

1.2.1 Pre-1975 Databases

Most of the published disturbance databases were developed from high-altitude flight research programs sponsored by the U. S. Air Force and NASA prior to the mid 1970's. Five programs provided data at altitudes above 40,000 ft. In chronological order these five programs were:

1. NASA U-2 airplane flights (1956 - 1964) over western Europe, Turkey, Japan and the United States (Coleman and Steiner, 1960);
2. NASA U-2 flights in support of the USAF High Altitude Clear Air Turbulence (HICAT) program (1964 - 1968), with flights over western Europe, Australia and New Zealand, the Caribbean and Panama, eastern Canada, and the United States including Alaska and Hawaii (Crooks, *et al*, 1967);
3. NASA XB-70 flights (1965 - 1966) over the southwestern United States (Ehernberger, 1968);
4. Operation Coldscan RB-57 flights (1969 - 1971) over the central and western United States and Ontario, Canada, and over the Pacific Ocean south of Panama (MacPherson and Morrissey, 1969);

5. NASA YF-12A flights (1973) over the southwestern United States (Ehernberger and Love, 1975).

The primary focus of these experiments was to obtain information on the frequency and intensity of clear air turbulence (CAT) as it relates to transient structural loads on supersonic airplanes and rocket launch vehicles. The bulk of the data collected thus consisted of direct measures of the test airplane vertical accelerations, a_n , read from VGH records. The accelerations *per se* were then used to calculate a "derived equivalent gust velocity," w_{DE} , as the measure of the vertical component of CAT. This calculation is according to

$$w_{DE} = K a_n \left[1 - \cos\left(\frac{2\pi x}{25C}\right) \right] \quad (1)$$

where K is an *airplane-specific*, dimensioned constant (unit time) which includes as parameters the slope of the airplane lift curve, equivalent airspeed, wing surface area, and a gust factor which depends on the airplane mass ratio (Pratt and Walker, 1953). The term in brackets is an assumed gust shape factor, where x is distance across a gust of length $25C$, where C is the mean chord length (i.e., x is defined in the interval $0 \leq x \leq 25C$).

The underlying concept in the above procedure is that a measured acceleration due to a gust may be used to derive an "effective" vertical gust velocity, which in turn can be used to calculate the acceleration on another similar airplane by reversing the process. The derived equivalent gust velocity, then, is not actually a physical quantity, but rather a gust load transfer factor as defined by eq. (1). A true vertical gust velocity, w , can be estimated from w_{DE} according to

$$w = \sqrt{\frac{\rho_0}{\rho(h)}} w_{DE} \quad (2)$$

where the term under the radical is the ratio of air density at sea level, to that at flight level. At 60,000 ft the true gust velocity is about 3 times the equivalent derived gust velocity; but this is a crude approximation at best. Thus although it is well suited to structural design analysis, w_{DE} is not a good measure of lateral gust magnitudes for inlet unstart analysis. Rather, the true gust velocity is required in this case. The NASA HICAT flights did provide a limited amount of such data.

1.2.2 Post-1975 Databases

Cancellation of the SST program in the 1970's meant the loss of interest in additional high-altitude research flights of the type just identified. However, discovery of the Antarctic ozone hole in the mid-1980's, along with the emergence of worrisome global climate change theories, rekindled interest in high-altitude flight research data to characterize not only upper atmosphere winds, but also atmospheric state and composition.

This led to development of the Meteorological Measurement System (MMS) for the NASA ER-2 airplanes (Scott, *et al*, 1990). The system includes a high resolution inertial navigation system (INS) for vector wind measurements to ± 1 m/sec; and a radome differential pressure system for measurements of airflow angles to $\pm 0.03^\circ$. This allows precise estimates of component wind speeds. Additionally, the system measures free-stream pressures and temperatures accurate to ± 0.3 hPa and $\pm 0.25^\circ\text{C}$, respectively. It includes a data acquisition system to sample, process, and store all measured variables on tape and on disc. The overall system response time is 0.5 sec. Data sampling rates are selectable at rates of 1 Hz and 5 Hz.

The MMS was first flown operationally in support of the Stratosphere/Troposphere Exchange Project Tropical Experiment (STEP Tropical) (Russell, *et al*, 1993). This experiment was conducted over northern Australia during the 1987 summer monsoon season. Eleven ER-2 flights were conducted out of Darwin, Australia during January and February. Five of the flights were over the Gulf of Carpentaria or the open ocean off the north coast of the continent. These flights were all within the Intertropical

Convergence Zone (ITCZ), the zone of intense convective activity near the equator. The MMS was also in continuous operation during the ER-2 ferry flights from Moffett Field, CA, to and from Darwin via Hickam AFB, Honolulu, and Anderson AFB, Guam.

The next two missions for the MMS were in support of the 1987 Airborne Antarctic Ozone Experiment (AAOE) (Tuck, *et al*, 1989); and the 1989 Airborne Arctic Stratospheric Expedition (AASE) (Chan, *et al*, 1990). During the AAOE, 12 ER-2 flights out of Punta Arenas, Chile, were conducted in August and September. Flight tracks were essentially south from Punta Arenas across the Drake Passage between South America and Antarctica, to 72°S, 70°W and return. The AASE flights were out of Stavanger, Norway. Fourteen research flights during January and February were flown from Stavanger northward across the Norwegian Sea to about 71° - 79°N and return. The AAOE and AASE ER-2 flights provide high-latitude disturbance data for both hemispheres. Again, the MMS was in continuous operation during the ferry flights for both missions. The ferry flight for the AAOE was over the eastern Pacific Ocean off the west coasts of North and South America, from Moffett Field, CA to Punta Arenas and return; that for the AASE was across the North Atlantic Ocean from Wallops Island, VA, to Stavanger and return.

Finally, measurements of the amplitudes and gradients of temperature transients were made over a four year period of Concorde operations over the eastern North Atlantic Ocean, the North Sea, the Indian Ocean, and the South China Sea (as well as over Europe and the North African and Middle East land masses) (Lunnon, 1992).

1.3 Database Assessment

The geographic areas within which the high-altitude disturbance data were collected are shown in Fig. 1.3-1a. Shown in Fig. 1.3-1b is the anticipated HSCT route structure during supersonic cruise (Wuebbles, *et al*, 1993). Comparison of the two figures shows that for the most part, the disturbance data were acquired outside the areas where HSCT supersonic cruise is expected. However, this fact does not preclude use of a given

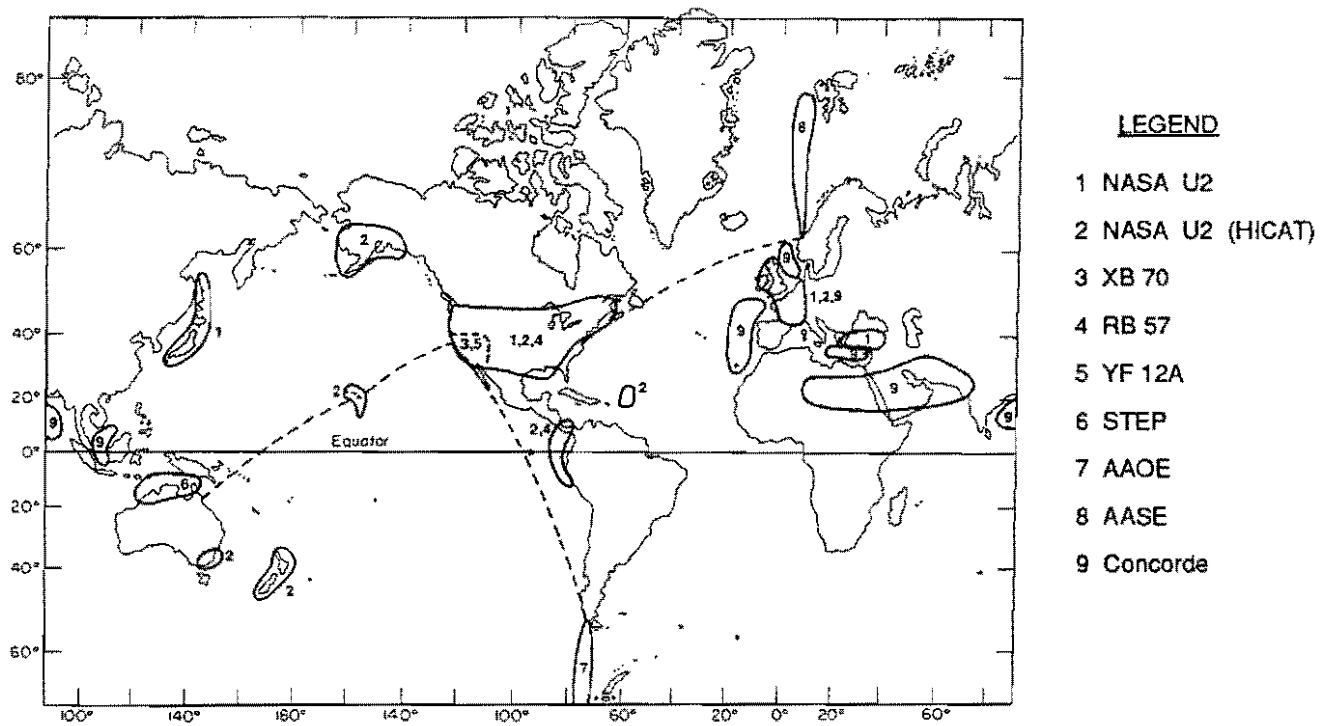


Fig. 1.3-1a. Geographic distribution of stratospheric disturbance flight tests.

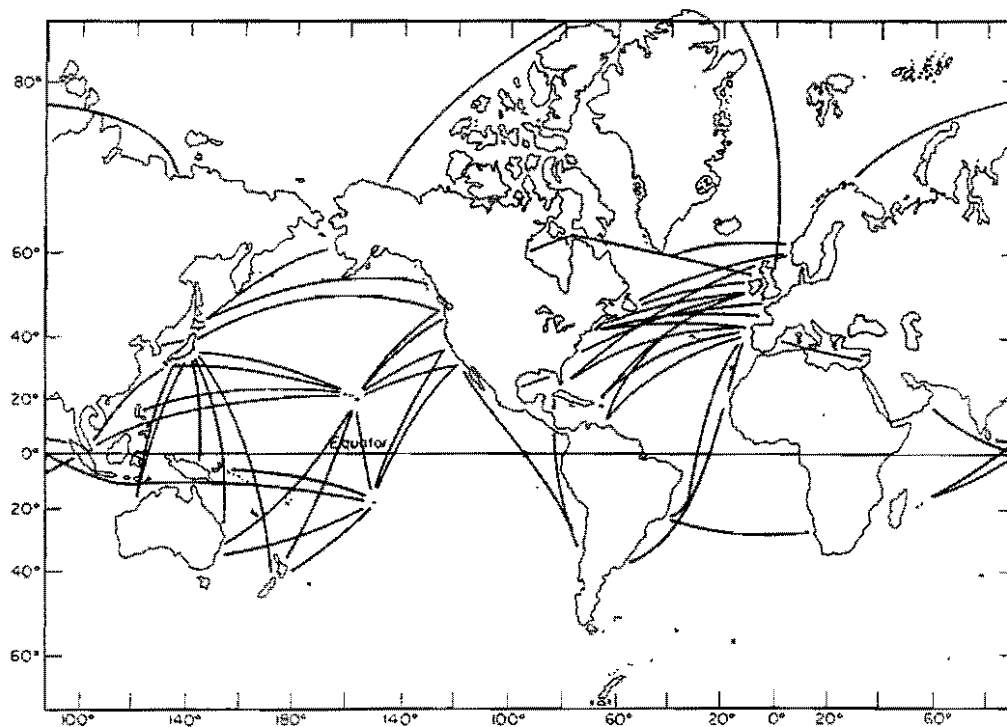


Fig. 1.3-1b. The anticipated HSCT route structure.

disturbance data set in the inlet unstart analysis; but it does require careful consideration as to how those data are best used for that analysis. This concept is developed further in the following sections.

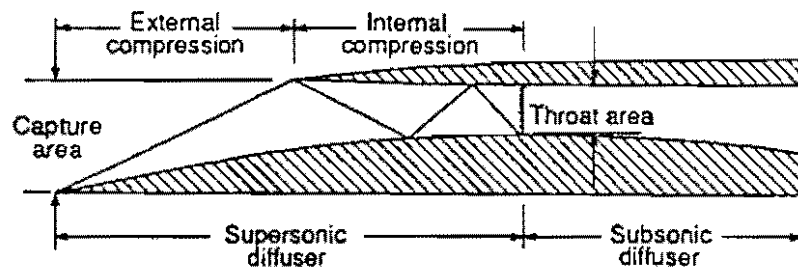
1.4 Summary

The extensive list of databases for characterizing the disturbance environment in the lower stratosphere is deceptive. Pre-1975 data are lacking in that they include for the most part only VGH data obtained over land masses. The post-1975 data are better suited to inlet unstart analysis *per se*, but they too lack in coverage relative to the anticipated HSCT route structure; and in data records that are too short for good statistical analyses of disturbance flight test results. Because of these database shortcomings, extrapolation is required to develop the global disturbance climatology needed for in inlet unstart probability analysis.

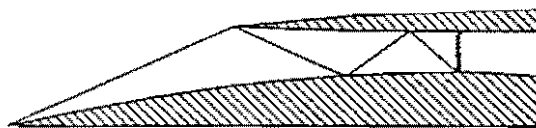
2.0 Problem Definition

2.1 Inlet Unstart Phenomenology

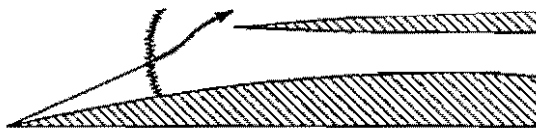
Mixed-compression inlets use the compression through a series of external and internal oblique shock waves to deliver subsonic flow to an engine compressor face at high efficiency with low drag, low bleed flow and high pressure recovery with minimum pressure distortion. In the "started" mode, the oblique shocks terminate with a normal shock slightly downstream of the inlet throat. The location of the shock directly affects inlet efficiency; peak performance is obtained with the normal shock at the throat station. However, terminal shock locations exactly at or upstream of the throat are unstable, and result in expulsion of the shock system. This condition is termed "inlet unstart." The result is drastic reduction in inlet mass flow and pressure recovery, with consequent increases in inlet drag and flow distortion. The shock wave patterns in the started and unstarted modes are shown schematically in Fig. 2.1-1 (Domack, 1991).



Mixed compression inlet design terminology



Started inlet



Unstarted inlet

Fig. 2.1-1. Mixed compression inlet shock patterns in the started and unstarted mode.

2.2 Inlet Flow Controls

Inlet unstart can be controlled through use of automatic control loops; i.e., a translating spike positioned according to a predetermined Mach number schedule, or variable ramps in a 2D inlet, can be used to maintain throat Mach number to within an acceptable unstart tolerance; and bypass doors and slots can be used to remove excess air from the inlet through exit louvers to maintain a stable terminal shock position slightly downstream of the throat station (Rachovitsky, 1970). The ideal control system such as this would counter any change in inlet mass flow. However, the inevitable lag in control loop response to rapidly changing free-stream conditions means that rapid changes above some response threshold might still result in throat choking or abnormal shock motions leading to unstart.

Nevertheless, automatic control loops are effective inlet unstart control mechanisms. The YF-12 airplane, for example, has not experienced a significant number of unstarts as a result of directional disturbances in inlet mass flow due to turbulence, because the inlet control was designed enough toward conservative operation that the disturbances have been well within the stability boundaries (Smith and Bauer, 1974). However, such conservative control settings reduce inlet performance to the economic disadvantage of an HSCT that requires high performance over long ranges.

2.3 Inlet Unstart Probability Analysis

The probability of inlet unstart thus becomes an important design parameter for the HSCT propulsion engineer. He wants an inlet design conservative enough to reduce the likelihood of unstart to a sufficiently remote level; but not too conservative so as to compromise the economic viability of the HSCT airplane.

Consider that two "events" must occur for an inlet to unstart. First, a disturbance must be encountered; and then it must be "strong" enough (as determined not only by disturbance amplitude but also period (cf. Section 3.1), to cause unstart. Call the occurrence of the disturbance encounter event E, and that of the "threshold" change in throat Mach number or shock

position of sufficient magnitude to cause unstart event y . Formally, the unstart probability can then be represented as the *joint* probability of events E and y , i.e., the probability of both events occurring simultaneously. In the parlance of probability theory, this is determined by the product of the *a priori* or "*prior*" probability of the event E , by the *conditional* probability of event y *given the occurrence of event E* (Ref. Hahn and Shapiro, 1967). In standard notation,

$$P_{\text{unstart}} = P(E, y) = P(E) \times P(y|E) \quad (3)$$

where $P(E, y)$ is the joint probability of the encounter and unstart threshold (the comma implies the word "and" in this functional notation); $P(E)$ is the prior encounter probability; and $P(y | E)$ is the conditional probability of the unstart threshold given the encounter (the vertical bar is read as the word "given").

Equation (3) is general in that it applies to both controlled and uncontrolled inlets. It is made specific to one case or the other by defining separate controlled and uncontrolled unstart thresholds; i.e., symbolically, by defining separately a y_c and a y_u , where the subscripts "c" and "u" mean "controlled" and "uncontrolled" respectively.

Carrying this a step further, consider now the impact that a small but finite probability of a control loop failure has on unstart probability. Call the failure event F , with prior probability $P(F)$. The probability of a *non-failure* is then $1 - P(F) = P(G)$, say. Unstart probabilities for *each* of the complementary control loop failure/non-failure events can be calculated from a straightforward expansion of eq. (3). Then because the failure and non-failure events are mutually exclusive, the probability of unstart from one *or the other* is simply the sum of the separate unstart probabilities (Hahn and Shapiro, 1967); i.e.,

$$P_{\text{unstart}} = P(E) [P(G) \times P(y|G, E) + P(F) \times P(y_u|F, E)] \quad (4)$$

where $P(y_c | G, E)$ is the conditional probability of the unstart disturbance

threshold for a controlled inlet, given both an encounter and a working control loop; and $P(y_u | F, E)$ is the conditional probability for the uncontrolled inlet, given a failed control loop and an encounter. Note that when $P(F) = 0$, $P(G) = 1$ and eq. (4) reduces to eq. (3).

Regardless of the case to be considered ($P(F) = 0$ or finite), the formalism of eq. (3) makes it clear that prior encounter probabilities, and conditional unstart threshold probabilities may be examined and discussed separately in their individual contribution to the joint unstart probability.

2.4 Summary

The inlet unstart probability is formally stated as a joint probability calculated as the product of the prior probability of encountering a disturbed atmosphere, by the conditional probability of a disturbance capable of causing inlet unstart during the encounter. This formalism makes possible the examination of the prior and conditional probabilities separately, in their individual contributions to the joint unstart probability. An expansion of the basic joint probability equation allows consideration of the probability of control loop failure to the overall unstart probability calculation.

3.0 The Prior Disturbance Encounter Probability

3.1 Analytical Approach

The prior disturbance encounter probability is the local frequency of occurrence of the disturbed environment. Thus occurrence *per se* can be treated as a dichotomous "yes" or "no" variate. The accumulation of disturbance data as needed to calculate occurrence statistics can therefore be made without too much regard for disturbance magnitude. However, with five separate parameters that might contribute to unstart to choose from (three wind vector components, temperature and pressure), the question comes up as to whether or not there is a single parameter which could serve as a proxy for all others as a *signature* disturbance for the "yes" or "no" query. Consider the following.

Temperature in the lower stratosphere tends to be nearly constant with altitude. As air parcels are displaced up or down due to disturbed flow in this "isothermal" stratosphere, temperatures change adiabatically at a rate of nearly 10 C/km of altitude displaced. Cooling occurs for upward displacements (parcel expansion), and warming results from displacements downward (parcel compression). The net result is displaced air parcels with "disturbed" temperatures (or kinematic pressures) that differ from the surrounding air mass; the greater the displacement, the greater the difference. The same effect is obtained with non-adiabatic, turbulent "mixing" of air parcels across mean wind and temperature gradients. In either case, it is the disturbed airflow that produces the disturbed temperature or kinematic pressure field.

Thus, vector wind and temperature disturbances go hand in hand, especially in the stratosphere; and the vertical gust can be taken as the signature disturbance parameter for calculating disturbance occurrence statistics. Furthermore, because the gust is treated as a dichotomous variate in this application, it matters not whether the gust is measured in terms of airplane accelerations *per se*, or of the derived equivalent or true gust velocities.

This makes possible use of the considerable pre-1975 database for developing disturbance frequency of occurrence statistics -- not, however, without ambiguity. This is because of differences in the criteria used by the various flight research programs to identify "rough air." For example, the criterion for the NASA U-2 flights was at least one vertical acceleration peak $a_n \geq 0.1$ g in the VGH record per minute of flight, whereas the a_n peaks for the XB-70 and RB-57 flights were 0.06 g and 0.35 g, respectively (Waco, 1976); the threshold acceleration for the YF-12 was 0.05 g (Ehernberger and Love, 1975). Beyond this, there is the difference in sensitivity to turbulence between different airplanes (cf. eq. (1)); e.g., it is likely the XB-70 would sense as "turbulence" long wave-type motions that would not be sensed by the slower flying U-2.

These sorts of factors -- differences in CAT detection thresholds, differences in airplane response to disturbances -- would produce different peak acceleration counts, and therefore different occurrence statistics, for a given flight test scenario. Allowances for these differences are included in published summaries of early flight test results (Waco, 1976); but uncertainties do persist. Nevertheless, the pre-1975 databases are pivotal in the following analyses of prior disturbance encounter probabilities.

3.2 Data Extrapolation

The bulk of the data for developing disturbance encounter probabilities are from areas outside the HSCT route structure, for altitudes below the inlet start altitude. Consequently, extensive extrapolation of those data is required to determine encounter probabilities in the areas and at the altitudes of concern. This means extrapolating high-altitude disturbance data obtained over land, to ocean areas. The paucity of such data over oceans requires that this be done.

Extrapolation always involves a measure of subjectivity; but it does produce credible results when done carefully in reference to sound physical principles. The relevant principles here are the well-documented correlations of disturbed air flow with a.) low Richardson numbers as the result of strong vertical shear of the horizontal wind near jet streams (Endlich and Mancuso, 1965; Vinnichenko, *et al*, 1973); b.) gravity waves propagating vertically through the stratosphere as triggered by mountains, cloud barriers or irregular jet stream dynamics (Ehernberger, 1992; Fovell, *et al*, 1992); and c.) regions of hydrodynamic instability with strong convective activity (Burns, *et al*, 1966). Ocean areas over which these conditions occur preferentially, are those over which atmospheric disturbances are most likely.

3.2.1 Jet Stream Correlations

In the stratosphere at HSCT altitudes, a high incidence of CAT is

expected near the wintertime, polar vortex jet stream, particularly in regions of confluence between separate branches of the stream (Reiter and Nania, 1964). Frequent CAT is also expected at the base of the stratosphere in any season, in association with mid-latitude tropospheric jet streams near the tropopause (Vinnichenko, *et al*, 1973). The Northern Hemisphere distribution of tropospheric jet streams in winter and summer is shown in Fig. 3.2-1 (Griffiths and Driscoll, 1982).

The occurrence of CAT in relation to tropospheric jet streams is shown in Fig. 3.2-2 by the two plots of the percent of flight miles in CAT versus height above mean sea level. The light solid line is from CAT occurrence data acquired during random, world-wide flights of commercial turbojet airplanes (Donely, 1971). The heavy solid line is a composite plot of similar data above 12.2 km (40 Kft) from the NASA U-2 and HICAT U-2 flights (Coleman and Steiner, 1960; Crooks, *et al*, 1967); and from flight tests below 12.2 km specifically designed to probe CAT in and near jet streams (Estoque, 1958). Note that at a height of about 10 km, jet stream CAT is about three times more likely than random CAT. This ratio decreases above and below 10 km. This is the nominal height of the mid-latitude tropopause, the preferred site for jet stream occurrence. The right hand scale in Fig. 3.2-2 measures height from this datum level.

The variation of tropopause height with latitude is shown in Fig. 3.2-3 (Kriese, 1992). Also shown as the dashed line in the figure, is the nominal height versus latitude of inlet start during climbout. This is in accordance with the Mach number schedule for the started inlet as shown in Fig. 3.2-4. The latitudinal variation of the inlet start altitude reflects the latitudinal variation at altitude of the speed of sound. The important thing to note here is that for operations out of airports in tropical and sub-tropical regions, inlets start in the troposphere. Continuing climbout across the tropopause will then subject the HSCT to the "worst case" environment for inlet unstart due to disturbances from strong vertical wind shear near low-latitude jet streams in particular, and near the tropopause in general.

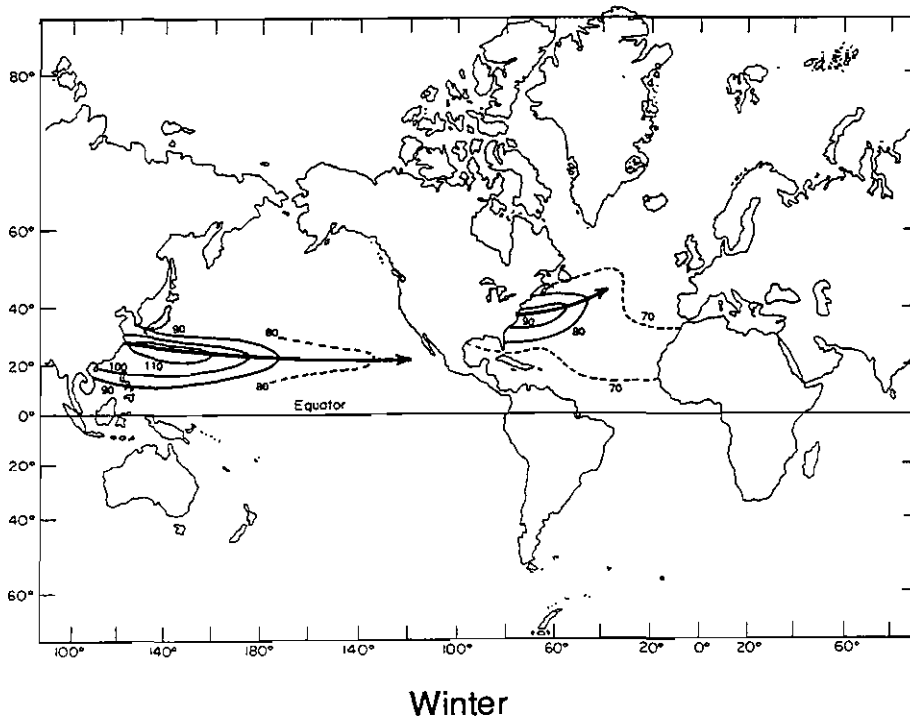
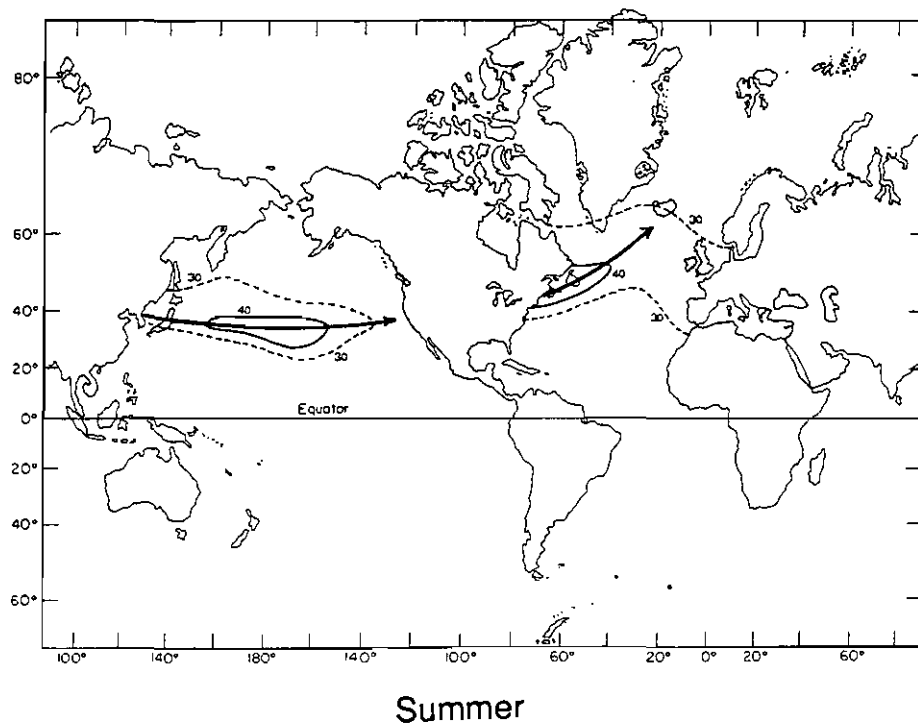


Fig. 3.2-1. Mean jet stream positions in the Northern Hemisphere summer (top panel) and winter (bottom panel). The heavy arrows mark the jet cores. The solid and dashed isopleths about the cores are isotachs labeled in knots.

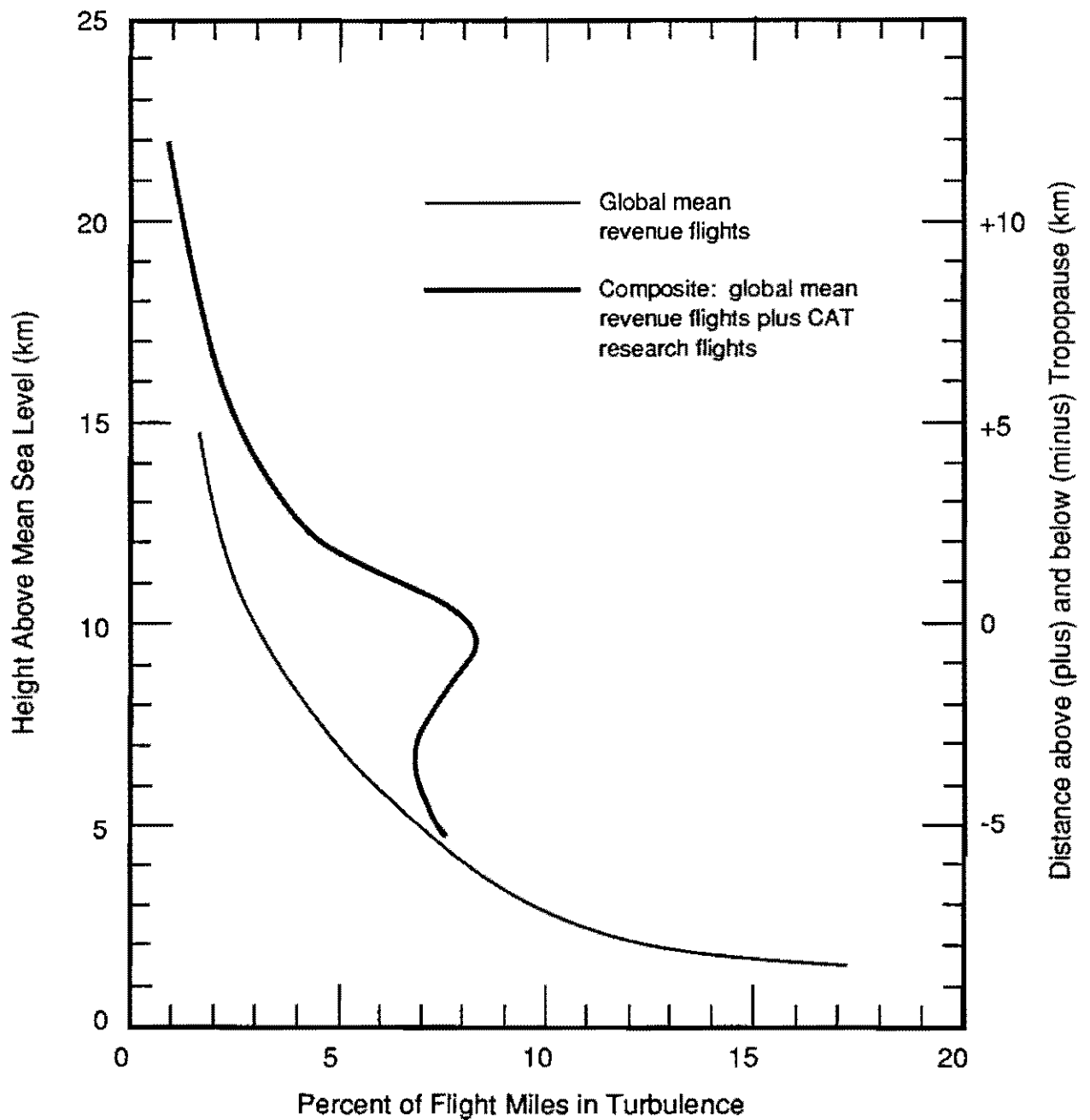


Fig. 3.2-2 Vertical profile of the probability of clear air turbulence (CAT). The maximum in the profile at a height of about 10 km is due to the preferential occurrence of jet streams near the tropopause.

Mean Seasonal and Annual Tropopause Heights

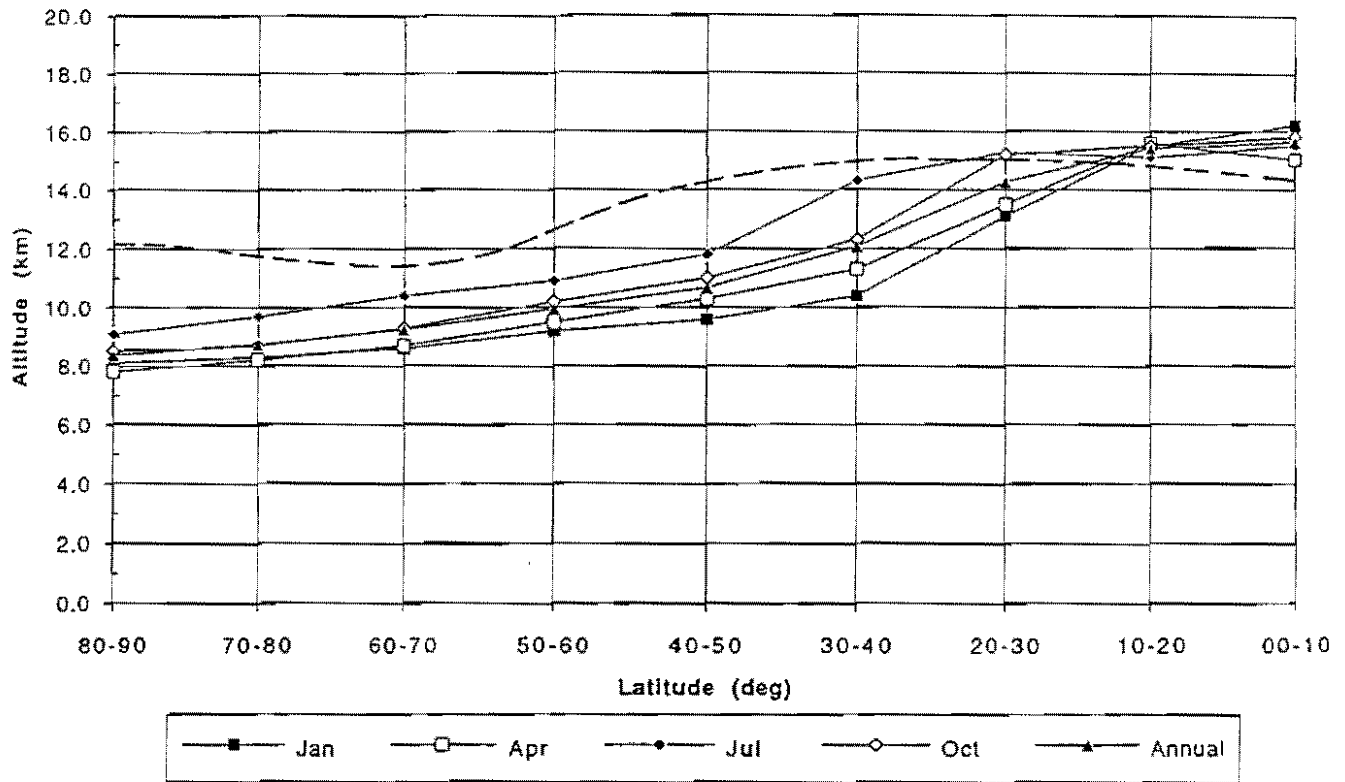
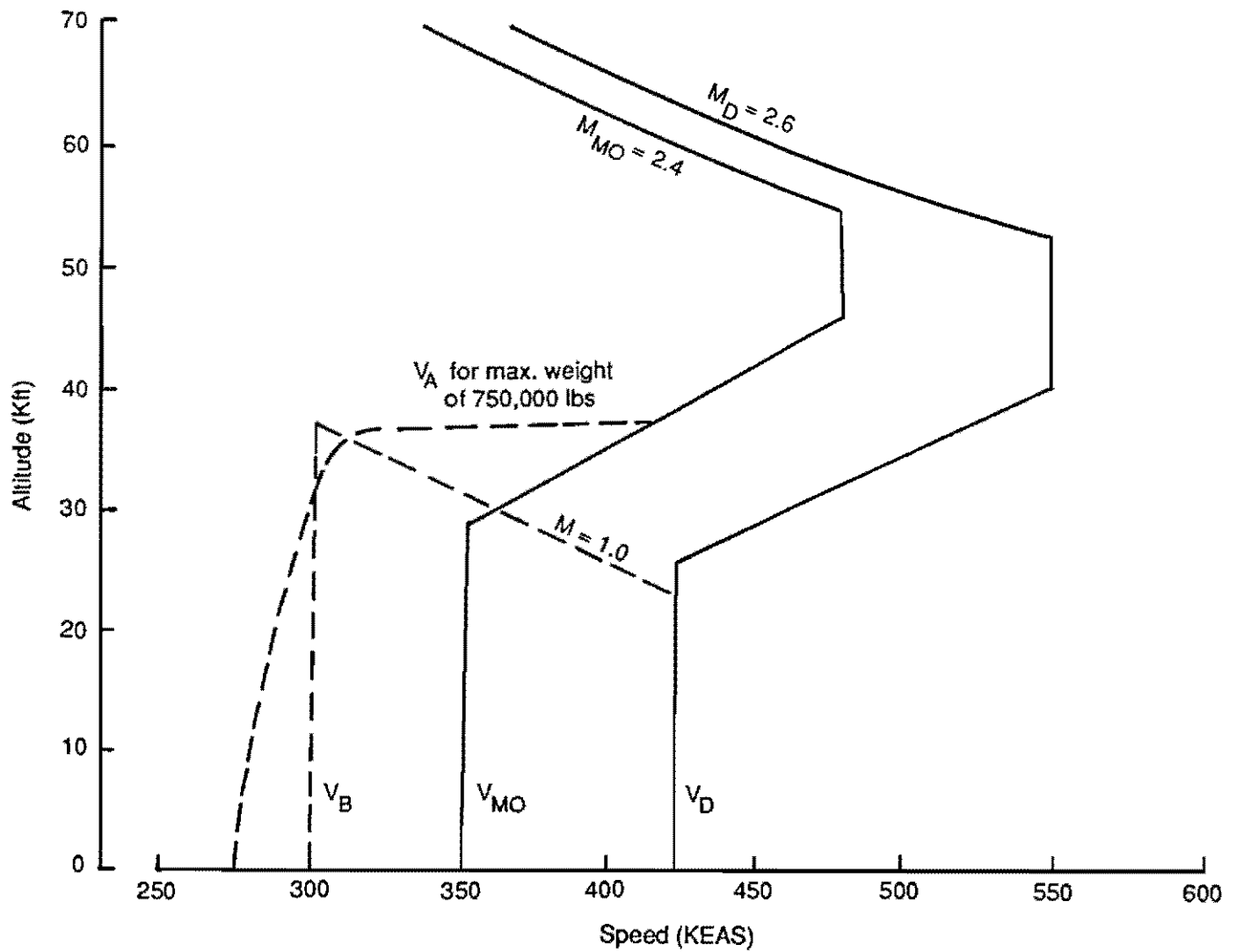


Fig. 3.2-3. Latitudinal variation of mean tropopause height (solid lines) and of the nominal mixed compression inlet start height (dashed line).



SYMBOLISM: KEAS = knots equivalent air speed
 V_{MO} = design maximum operating speed
 V_A = design maneuvering speed
 V_B = design speed for maximum gust intensity
 V_D = design dive speed

Fig. 3.2-4. Mach number schedule for a mixed compression inlet.

3.2.2 Gravity Wave Correlations

Given favorable vertical profiles of temperature and horizontal wind speed, gravity waves will be triggered in the troposphere by flow over undulating terrain or cloud barriers, or by irregular jet stream dynamics (Ehernberger, 1992; Fovell, et al, 1992). Amplitudes of these waves tend to grow in proportion to the inverse square root of the ratio of air density at altitudes h_1 and h_2 ($h_2 > h_1$), until they become unstable, break due to Kelvin-Helmholtz instability, and degenerate into random disturbances in both the local air flow and temperature fields. Ehernberger considers this the predominant cause of stratospheric CAT (Ehernberger, 1992).

Scoggins and Incrocci (1973) used the XB-70 flight test data (Section 1.2.1) as evidence to show a direct relationship between conditions in the troposphere favorable for standing mountain waves, and the occurrence of CAT in the stratosphere. Further analysis of the flight data in light of this relationship showed that 89 percent of regions of widespread CAT were in expected mountain wave areas (Possiel and Scoggins, 1976). Also, data from the RB-57 Operation Coldspan flights (Section 1.2.1) indicated nearly 3.5 times the frequency of occurrence of CAT over mountainous terrain than over water (MacPherson and Morrissey, 1969). More recently, Nastrom and Eaton (1993) correlate tropospheric gravity wave activity with enhanced turbulence in upper air radio refractivity, as measured with a VHF profiling radar at White Sands Missile Range. In the dry stratosphere, a disturbance in refractivity is essentially a disturbance in air temperature.

Given the right humidity profile, clouds will form at the crests of mountain waves but not in the troughs. Such cloud scenes are clearly visible in satellite imagery (e.g., Fig. 3.2-5), and are seen on average about one day in three over hilly country in temperate latitudes (Wallace and Hobbs, 1977). They confirm pre-satellite analyses that indicated mountain waves could extend and cause CAT hundreds of miles downwind of source regions (Harrison and Sowa, 1966). Thus increased disturbance probabilities at HSCT altitudes are expected off the lee shores of major land masses and in the lee of ocean islands. It does not take much of an island to cause a mountain wave. Tiny St. Kilda Island, about 200 Km (124 miles) west of Scotland,

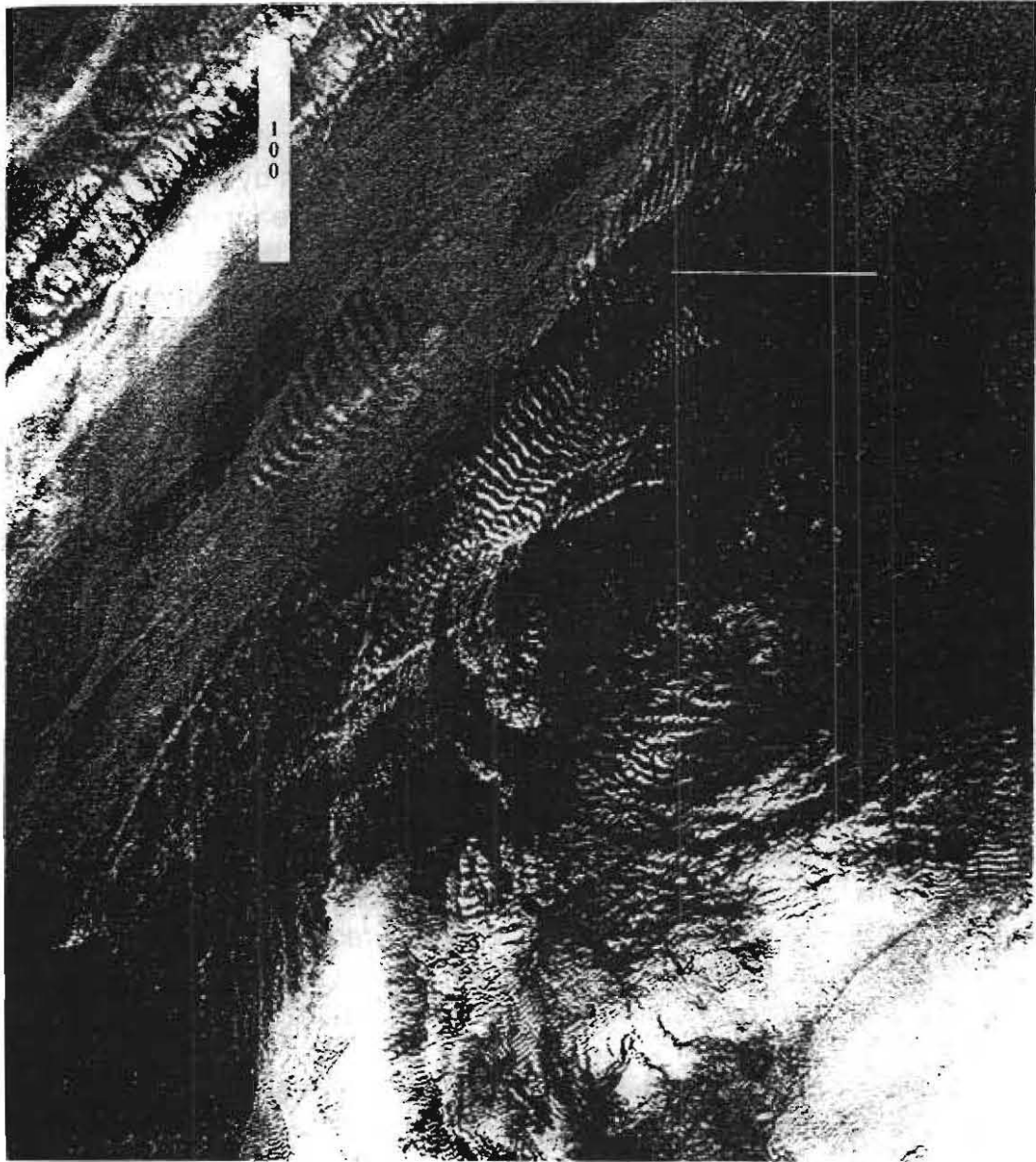


Fig. 3.2-5. Standing wave clouds over the Outer Hebrides and offshore islands of Scotland (Scorer, 1986, courtesy of Simon and Schuster International Group Publishing House).

maximum terrain elevation of 425 m (1394 ft), caused the striking "ship wave" in the upper left quadrant of Fig. 3.2-5. Similar waves often extend downwind of the Azores for nearly 1000 km (620 miles) (Scorer, 1986).

3.2.3 Convective Cloud Correlations

Strong convective storms cause vertically propagating gravity waves in either of two ways, i.e., via the "obstacle effect," in which the pressure fields produced by persistent convective updrafts or downdrafts act as obstructions to the environmental horizontal flow thus generating the waves; or via the "mechanical oscillator effect," in which oscillating updrafts and downdrafts impinging on the tropopause cause oscillating displacements of the isentropic surfaces (surfaces of constant entropy) at the base of the stratosphere, which in turn excite the waves (Fovell, *et al*, 1992). In either case the net result is the same as for the case of gravity waves produced by flow across mountain barriers; i.e., the waves propagate vertically, become unstable, and break to cause disturbances at HSCT altitudes.

Direct evidence of breaking stratospheric gravity waves in association with strong tropical convection has been documented by Pfister, *et al* (1986). The evidence was in data obtained during the NASA ITCZ experiment, which was conducted in Panama during July, 1977 (Poppoff, *et al*, 1977). This was a precursor experiment to the NASA STEP Tropical experiment (Section 1.2.1). On four days of the two week ITCZ experiment, air temperature was measured from a U-2 airplane flying a north-south flight pattern at altitudes ranging from 14.1 to 21.3 km. The airplane flight speed was about 200 m/sec, and the data sampling rate was 1 Hz. Shown in Fig. 3.2-6 are the temperature records obtained on 27 July 1977, at four flight altitudes. The record from 19.85 km was singled out by Pfister, *et al*, (1986) as especially indicative of gravity wave motion, because of the regularity of the measured temperature transients between about 8.5° to 9° N. latitude. The fluctuation period was about 23 sec, implying a gravity wave length of about 4.6 km. The comment from the pilot of "rough flying" at 19.85 km suggests CAT due to breaking waves caused by Kelvin-Helmholtz instability.

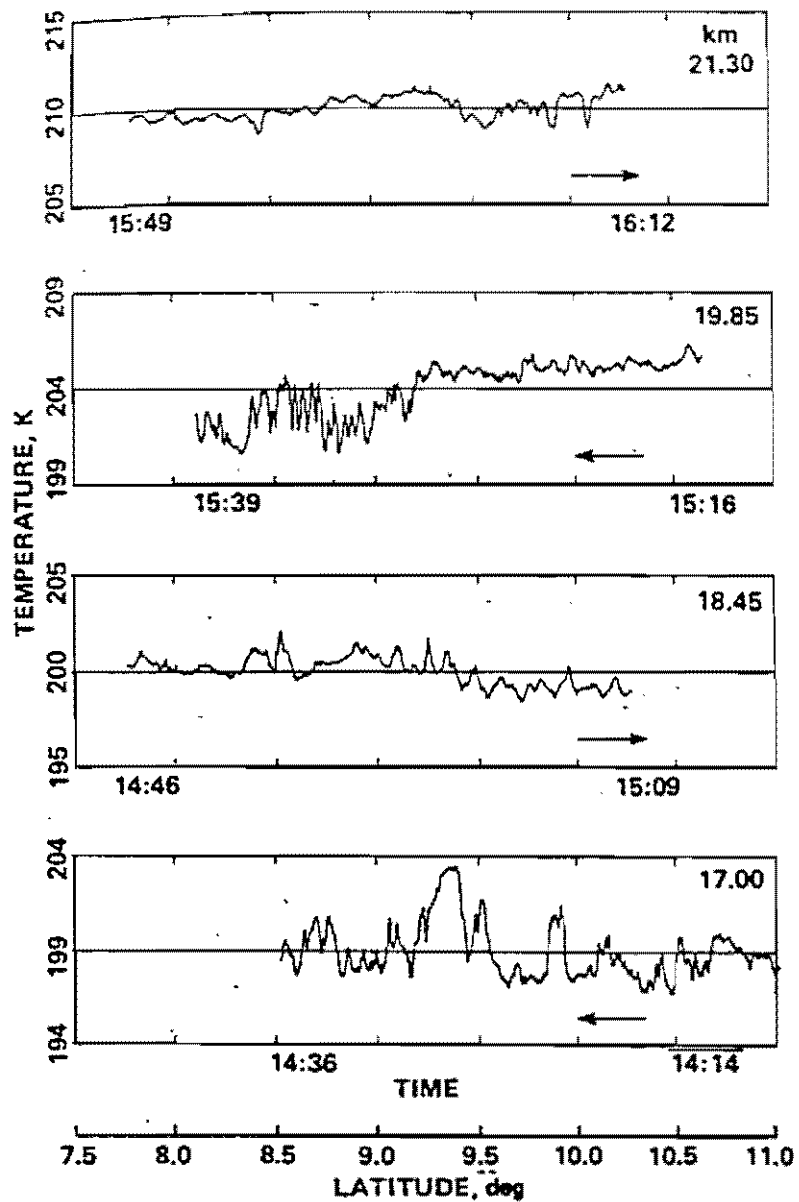


Fig. 3.2-6. U-2 temperature records at four altitudes over Panama. The record at 19.85 km altitude between about 8.5N and 9.0N latitude is considered evidence of a convective cloud-induced gravity wave.

Satellite cloud pictures confirm the ITCZ as a permanent zone of strong convective activity that circles the globe (Fig. 3.2-7). It is usually made up of a series of distinct cumulus cloud clusters, with scales of the order a few hundred kilometers, which are separated by regions of relatively clear air. It is almost never found exactly at the equator; but is particularly persistent and well-defined over the Pacific and Atlantic between about 5° and 10° N latitude, and occasionally appears in the Pacific between 5° and 10° S. Its seasonal extreme locations are shown in Fig. 3.2-8 (Griffiths and Driscoll, 1982). This plot serves to locate the preferred regions of stratospheric disturbances due to strong convective activity over the oceans.

3.3 Global Distributions of Disturbance Encounter Probabilities

Shown in Fig. 3.3-1 are global distributions over oceans, of the prior probabilities of disturbance encounters at HSCT supersonic cruise altitudes for summer and winter. These distributions are the result of due consideration *in combination*, of all the relationships between disturbances and bulk atmospheric structure that serve to mark the preferred regions for disturbance activity (Section 3.2). The distribution maps indicate that prior disturbance probabilities are highest when such regions overlap. This is shown by occurrence "hot spots" over the western Pacific ocean off the coast of Japan, the result of frequent strong jet stream activity in this region in combination with topographically-induced gravity waves; and over Indonesia because of gravity wave activity caused not only by topography, but also by strong convective activity in the ITCZ.

The maps of prior disturbance encounter probability in Figs. 3.3-1 are in accord with the limited amount of disturbance data over open oceans there is to work with. Refinements to the maps will be required as additional *in situ* stratospheric disturbance data over oceans become available. Future NASA/NOAA environmental research programs using ER-2 airplanes for meteorological measurements would be one source of such data. Another source would be data from commercial B747 airplanes during scheduled transoceanic operations (cf. Section 5.3.1.1).

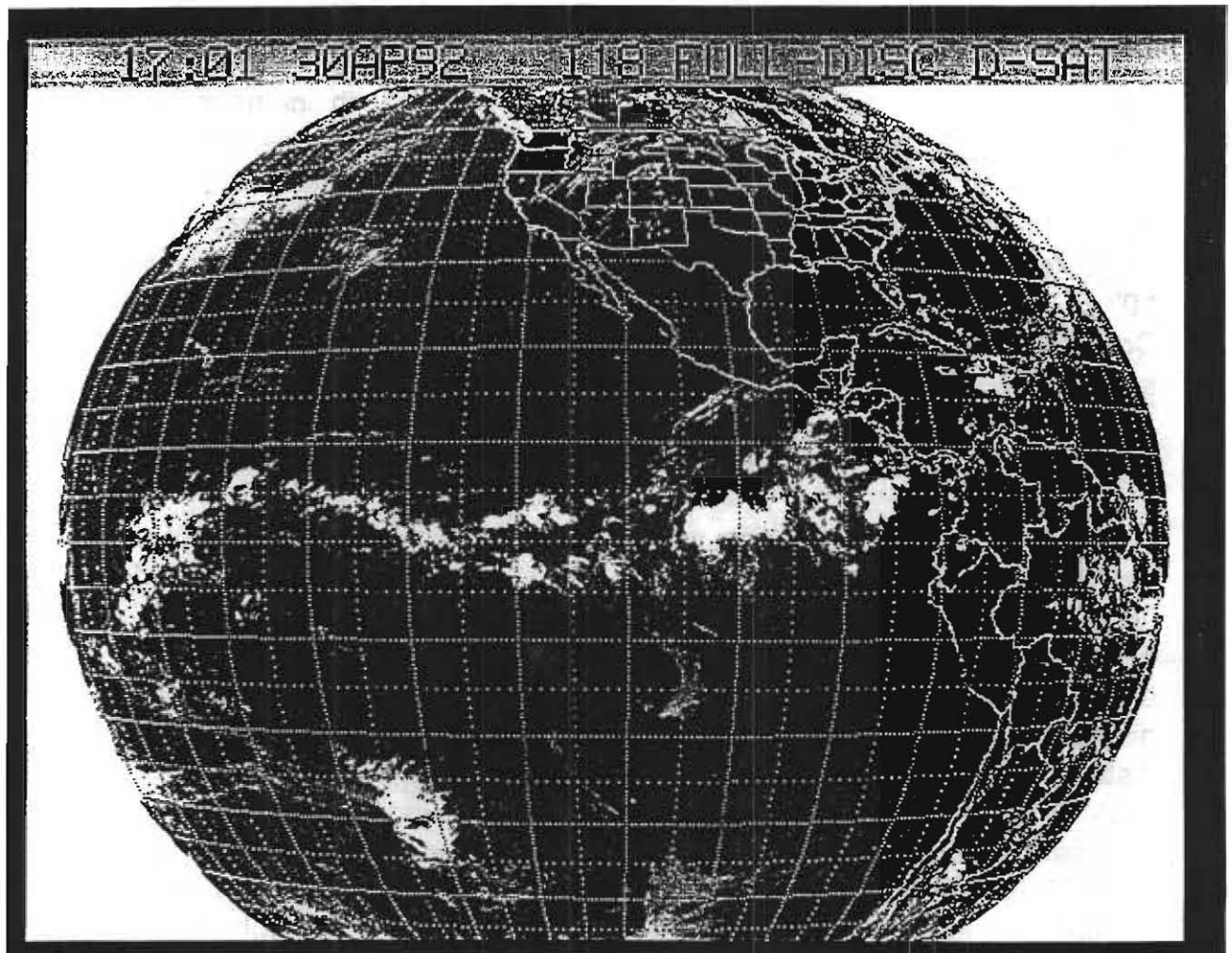


Fig. 3.2-7. Convective cloud band near the equator marking the Intertropical Convergence Zone (ITCZ).

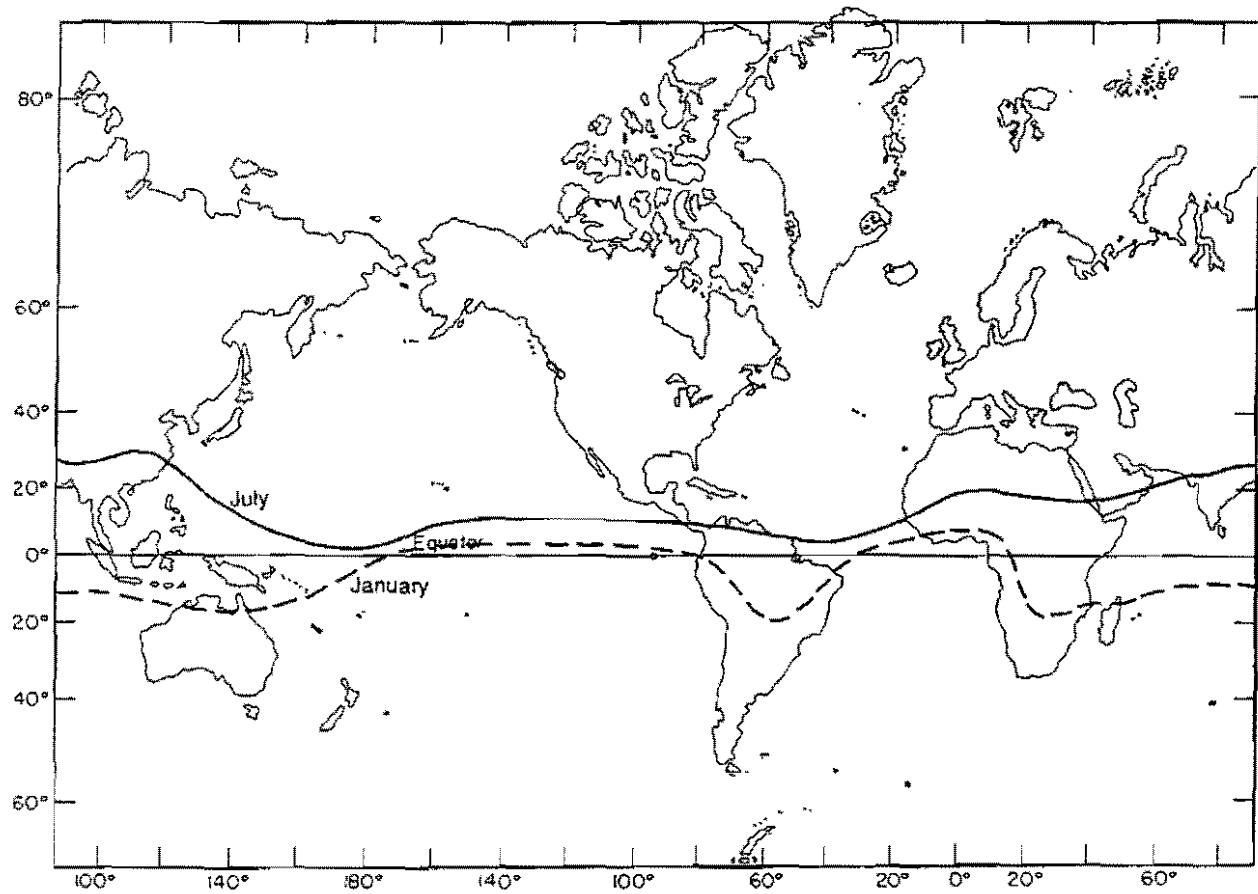


Fig. 3.2-8. Summer and winter mean positions of the ITCZ.

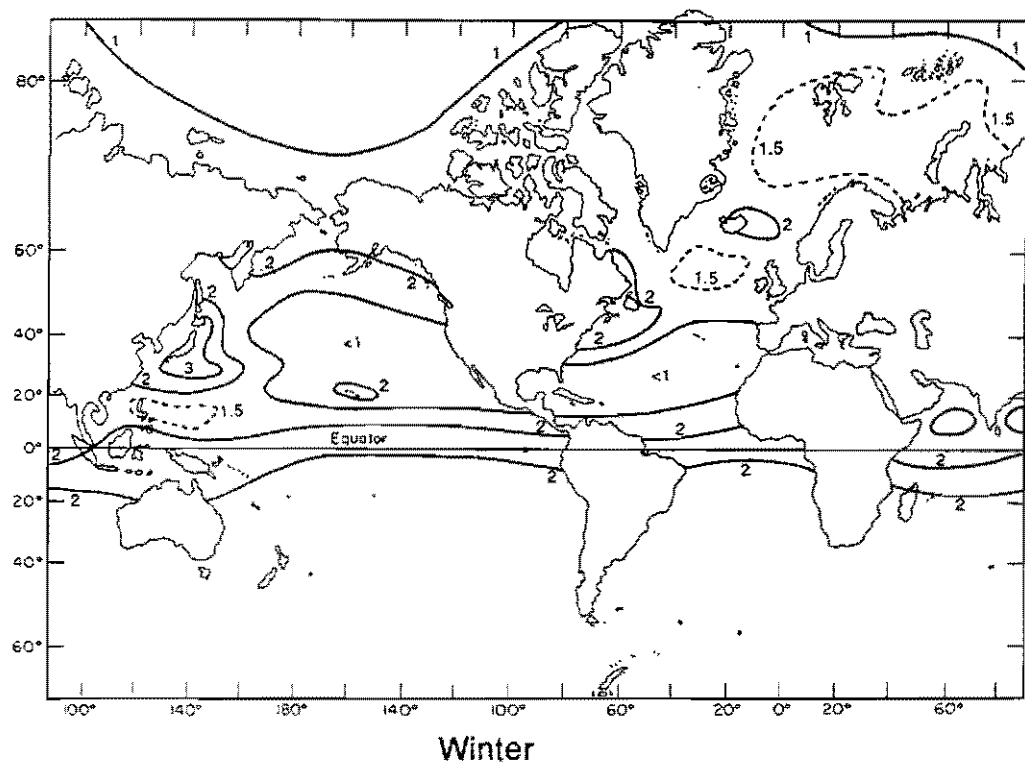
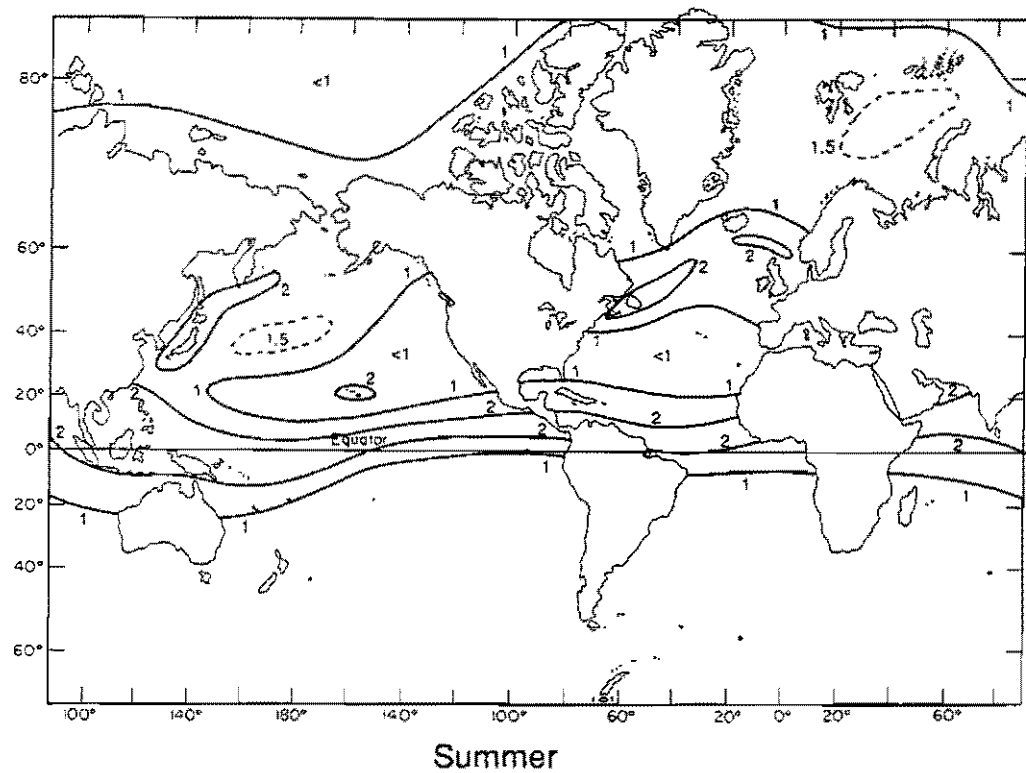


Fig. 3.3-1. The prior probability of encountering disturbances over Northern Hemisphere oceans. Lack of data precludes a similar analysis for oceans in the Southern Hemisphere.

3.3 Summary

The global distributions of the prior probability of encountering disturbances at HSCT altitudes over oceans in winter and summer are mapped in Figs. 3.3-1. The preponderance of the data used to prepare the maps were from areas outside the HSCT route structure, for altitudes below the inlet start altitude. Consequently, extrapolation of available data was required to determine encounter probabilities for the areas and at the altitudes of concern. This extrapolation was in reference to established relationships between the occurrence of disturbances and bulk atmospheric characteristics. The requirement for the extrapolation identifies a need for additional stratospheric disturbance data over ocean areas to confirm and/or refine the data presented here.

4.0 The Conditional Unstart Threshold Probability

4.1 Analytical Approach

The conditional unstart probability is the probabilistic response of the inlet to a disturbed environment. Two different methods have been developed to describe inlet instability as caused by atmospheric disturbances. They are similar in that both use linear inlet response functions to calculate time-dependent changes in inlet operating conditions imposed by free-stream disturbances. The basic difference between them is the way in which the disturbances are characterized. The first treats them as a family of discrete disturbances of specified disturbance amplitude and disturbance "gradient" (Rachovitsky, 1970); the second considers them a continuous random process describable in terms of spectral densities (power and cross-spectra) of zero-mean disturbance fluctuations (Barry, 1973). These two methods are discussed in order.

4.1.1 Discrete Disturbance Unstart Probability

The discrete disturbance unstart probability analysis starts by representing disturbances as populations of two types of symmetric,

triangular waves, one 90 degrees out of phase with the other. Both are completely defined by the disturbance amplitude and the positive disturbance gradient (Fig. 4.1-1). Given this representation, the analysis proceeds as sketched in Fig. 4.1-2. The idea illustrated by the figures is as follows.

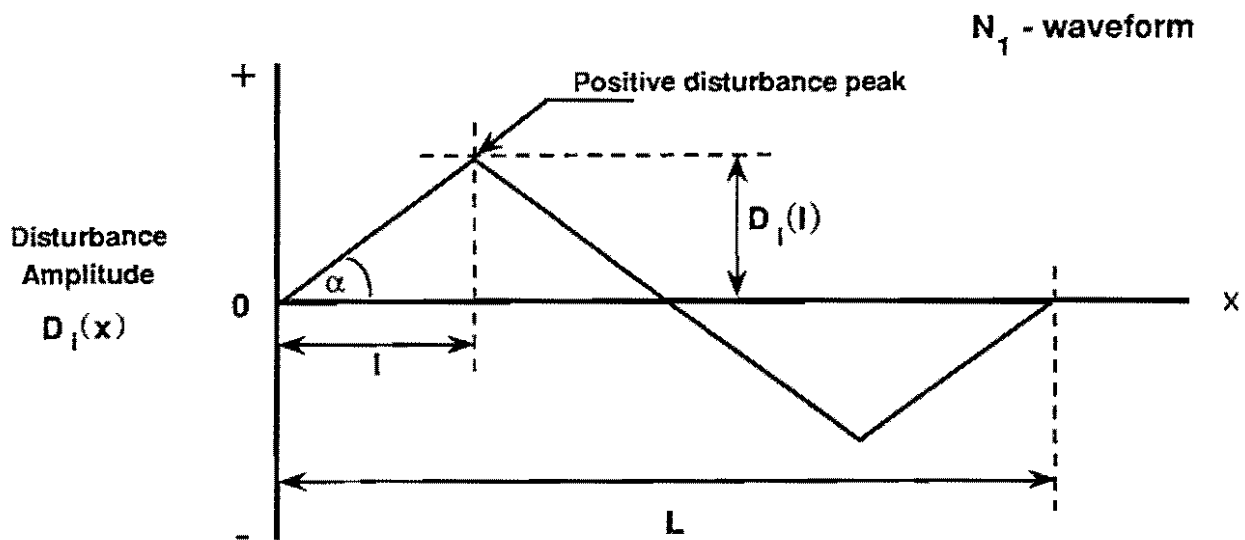
Consider by way of example an N_1 -waveform of disturbance D_i , with the potential for causing inlet unstart. Input this disturbance into a mathematical model of the inlet and its controls (as determined from inlet mass flow simulations), and calculate the output response of the inlet flow variables (throat Mach number, M_{th} , and shock position X_{th}). Whether or not the particular disturbance causes inlet unstart either by throat choking or by the normal shock moving upstream to the throat, is *determined by the disturbance gradient in relation to the disturbance peak amplitude, $D_i(l)$* . That is, for a given $D_i(l)$, there exists a particular gradient D'_i which causes unstart. The simulation example in Fig. 4.1-2 shows unstart due to a choked throat, and the inlet is said to be Mach number sensitive to disturbance D_i . The simulated unstart gradient may differ for the two wave types; if so, the smaller of the two is considered the critical unstart gradient, D'_{ic} .

Over a range of disturbance gradients for a range of disturbance amplitudes, the conditional unstart probability is given by (cf. eq. (3))

$$P(y|E) = \int_0^{\infty} \left[\int_{D'_{ic}}^{\infty} f(D_i, D'_i) dD'_i \right] dD_i \quad (5)$$

where $f(D_i, D'_i)$ is the joint probability density function (pdf) of disturbance amplitudes and gradients (again the comma implies the word "and"); and $D'_{ic}(D_i)$ expresses the dependence of D'_{ic} on D_i .

The meanings of the integrations in eq. (5) are explained in reference to the data shown plotted in Figs. 4.1-3a and 3b as follows. Fig. 4.1-3a is the pdf histogram of temperature disturbance amplitudes and gradients as measured over a four year time period during supersonic cruise of the Concorde airplane; Fig. 4.1-3b is the bi-variate ("two-dimensional") normal



x = Distance along airplane flight path

L = Disturbance wavelength

$l = L/4$ = quarter wavelength

$D_i(l)$ = Peak disturbance amplitude

$$\tan(\alpha) = \frac{dD_i(x)}{dx} = \frac{D_i(l)}{l} = \text{disturbance gradient}$$

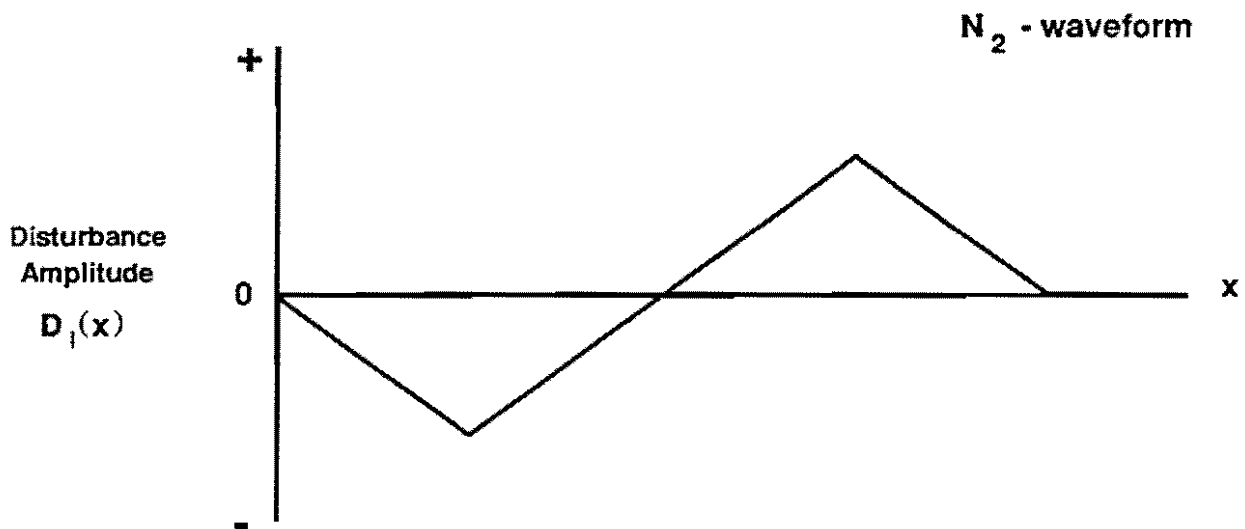
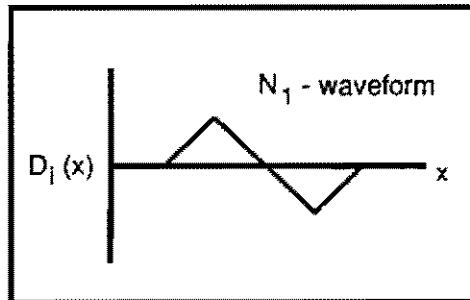
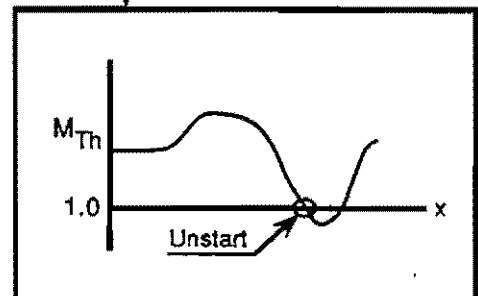
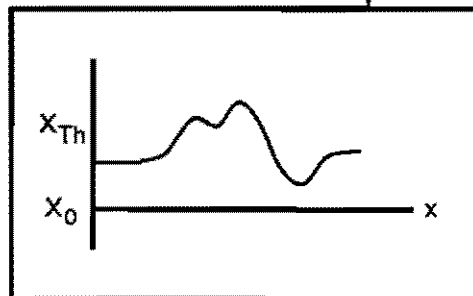


Fig. 4.1-1. Two discrete disturbance waveforms.

ATMOSPHERIC DISTURBANCE INPUT



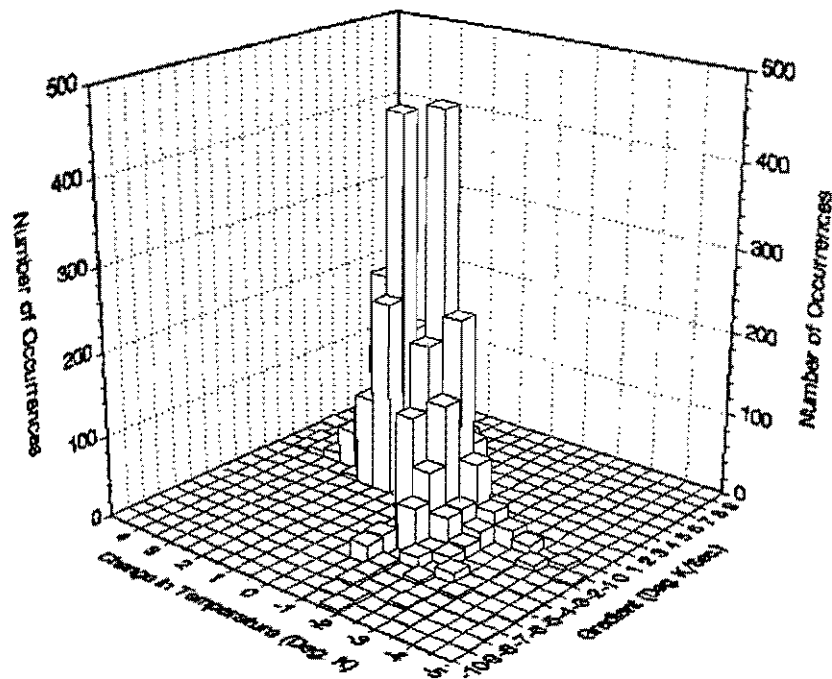
MATHEMATICAL RESPONSE MODEL
for
INLET and INLET CONTROLS



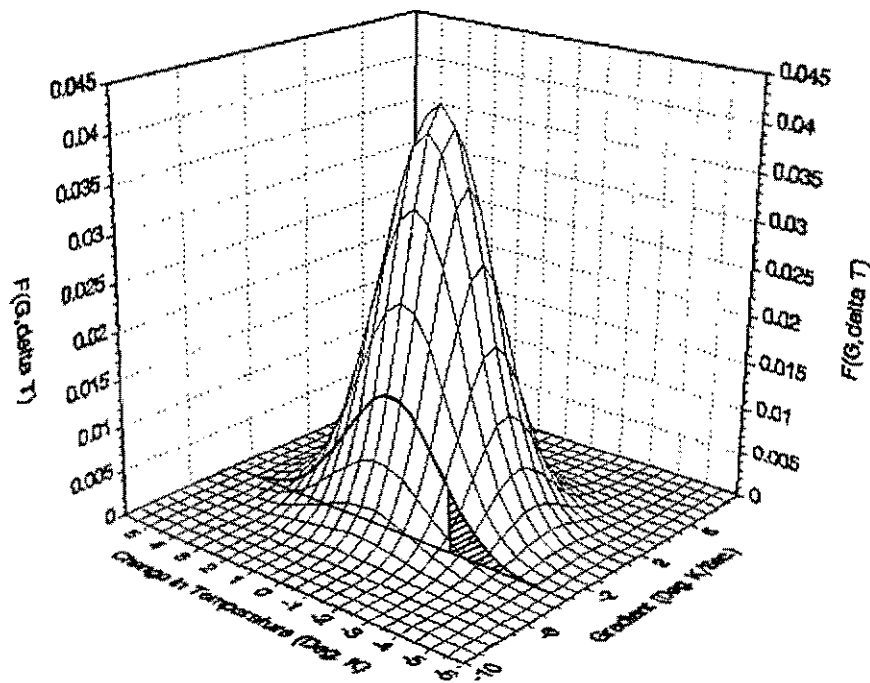
INLET RESPONSE OUTPUT

X_{Th} = Throat shock position
 X_0 = Shock position unstart threshold
 M_{Th} = Throat Mach number
 $M_{Th} = 1.0$ = Throat Mach No. unstart threshold

Fig. 4.1-2. Scheme for simulating the response of inlet flow variables to a discrete disturbance.



a.) Histogram



b.) Probability density function

Fig. 4.1-3. a.) Joint histogram of temperature disturbance amplitudes (left hand abscissa) and gradients (right hand abscissa) as measured during Concorde flights. b.) Bivariate normal probability density function fit to the illustrated histogram.

distribution which was fitted to the measured data. In reference to the latter figure, the inner integral in eq. (5) along the D'_i axis gives the area under the tail of the marginal, one-dimensional pdf for a given disturbance amplitude; this is the conditional unstart probability *at that amplitude*. The outer integral then, over all disturbance amplitudes, gives the "volume" under all marginal pdf tails for the exceedance probability of all temperature gradients greater than the critical value. This is the conditional unstart probability given by eq. (5) as called for by eq. (3).

Equation (5) identifies the two-dimensional pdf as basic to an unstart probability analysis for discrete disturbances. However, in reality there are five different free-stream disturbances acting singly or in combination if they are correlated, that could cause inlet unstart (three vector wind components, temperature and pressure). Thus the two dimensional pdf with the attendant double integration illustrated by eq. (5) becomes a ten-dimensional pdf (five parameters, five gradients) with an accompanying tenfold integration for the complete conditional unstart probability analysis.

As the name implies, the discrete disturbance approach is well suited to unstart probability analysis due to a truly isolated event like, say, an encounter with the shock wave or the wake from a passing HSCT airplane. In this case, the disturbance profile across the shock or the wake can be given a deterministic waveform like, for example, the triangular wave in Fig. 4.1-2. However, for natural disturbances the discrete disturbance approach suffers in that natural disturbances do not occur as transients of a single waveform with arbitrary amplitude and wavelength; instead they occur over a continuous range of waveforms. This is recognized in the approach to unstart probability analysis described in the next section.

4.1.2 Continuous Disturbance Unstart Probability Analysis

As for discrete disturbances, the unstart probability analysis for continuous disturbances starts with the calculation of a linear response of the inlet flow variables to free-stream disturbance inputs. The difference is, here the computational process deals with a statistical rather than a deterministic description of the disturbance.

Represent a disturbance D_i as the zero-mean fluctuation of free-stream parameter i about its mean value. Let y denote a dependent inlet flow variable (M_{th} or X_{th}) that responds to disturbance D_i according to the equation

$$y(t) = \int_0^{\infty} h_i(\tau) D_i(t - \tau) d\tau \quad (6)$$

which yields the spectral relationship (Dutton, *et al*, 1969)

$$S_y(f) = |H_i(f)|^2 S_i(f) \quad (7)$$

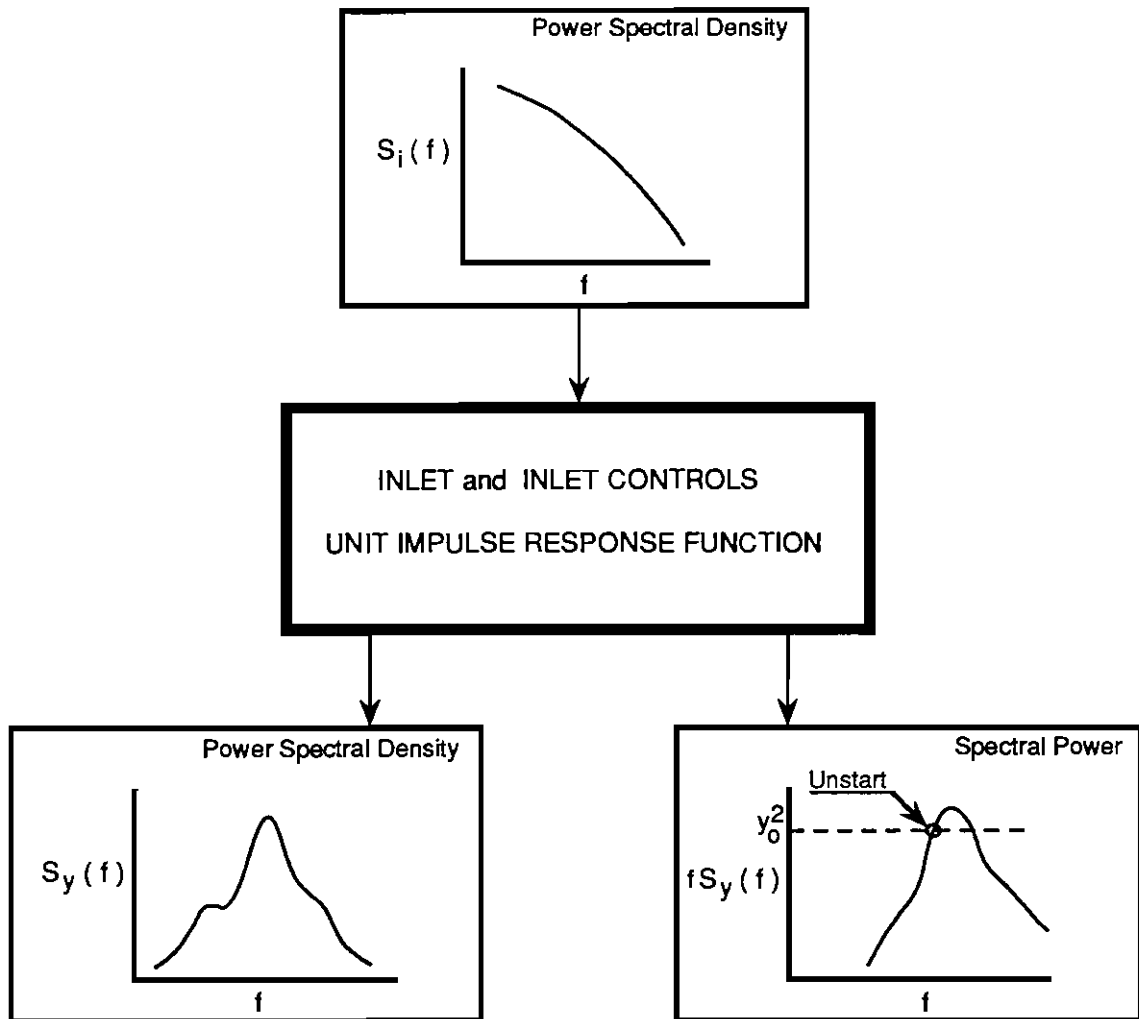
Equation (7) says that as the linear system described by eq. (6) is forced by the random free-stream disturbances, its Fourier transform produces a power spectral density (PSD) of the dependent inlet flow variable y that is in direct proportion to the spectral density of the input disturbance. The proportionality factor is the square of the modulus of the complex "system response function" as defined by the LaPlace transform

$$H_i(f) = \int_0^{\infty} h(\tau) e^{-if\tau} d\tau \quad (8)$$

The relationship between input and output spectra as given by eq. (7) is shown schematically in Fig. 4.1-4, the analogy to Fig. 4.1-2. The system response functions for the controlled, mixed compression inlet determine the effective bandwidths of the inlet mass flow controls as they act to prevent inlet unstart.

Again, multiple disturbance components can act together in causing inlet unstart. Each of the disturbances is characterized by a real power spectral density, and their interrelationships by complex cross-spectral density functions. Barry (1973) gives the following equation for the power spectral density of the output of a multiple-input linear system:

ATMOSPHERIC DISTURBANCE INPUT



INLET RESPONSE OUTPUT

$S_i(f)$ = Disturbance power spectral density: units (mean square D) / (cyc / sec)

$S_y(f)$ = Mass flow variable power spectral density: units (mean square y) / (cyc / sec)

y_0 = Unstart threshold for mass flow variable y

$f S_y(f)$ = Spectral power of mass flow variable y : units (mean square y)

Fig. 4.1-4. Scheme for simulating the response of inlet flow variables to continuous disturbances.

$$S_y(f) = \sum_{i=1}^N \sum_{j=1}^N H_i^*(f) H_j(f) S_{ij}(f) \quad (9)$$

for N input disturbances; $S_y(f)$ is again the output power spectral density, $H_i(f)$ is the system transfer function for input i , and $H_i^*(f)$ is its complex conjugate. The same notation holds for some other disturbance j . Note now the use of the double subscript on the input disturbance PSD. With this notation, $S_{ij}(f)$ is the complex cross-spectral density function of inputs i and j , as given by the Fourier transform of the i,j cross covariance function; $S_{ii}(f)$, is the PSD or "variance spectrum" of disturbance i , as the Fourier transform of its autocovariance function.

By expanding eq. (9), Barry (1973) shows that there are four power spectra and six complex spectral density functions to calculate unstart probability due to throat choking (i.e., $y = M_{th}$); and five power spectra and ten complex spectral densities to calculate unstart from the shock moving to the throat (i.e., $y = X_{th}$). However, anticipating the results of Section 5.2, the spectrum analyses of ER-2 stratospheric disturbance data show that cross-spectra at the higher "uncontrolled" input disturbance frequencies (cf. Section 2.2) tend toward zero (implying isotropic disturbances). The expansions of eq. (9) can then be stated in terms only of disturbance PSD's or variance spectra, i.e.,

$$S_y(f) = \sum_{i=1}^N |H_i|^2 S_{ii}(f) \quad (10)$$

The calculation of throat Mach number and shock position PSD's is then greatly simplified.

Again, unstart occurs when the amplitudes of output disturbances in the inlet flow parameters exceed inlet design tolerances, *and* when they occur at a frequency greater than the inlet control systems can handle. For a given disturbance input, the estimate of the probability of this happening is

based on the following parameter (Barry, 1973; Turner and Hill, 1982)

$$A_y = \sqrt{\frac{\int_0^\infty S_y(f) df}{\int_0^\infty S_{ii}(f) df}} = \frac{\sigma_y}{\sigma_i} \quad (11)$$

This is a positive constant written as the ratio of the *complete* rms amplitude of the output fluctuations in inlet flow parameter y , σ_y , to the complete rms amplitude of the input fluctuations of the free-stream disturbance i , σ_i . Barry (1973) notes that this ratio may be determined from truncated rather than complete integrals under the radical, by integrating to a finite high cut off frequency, f_{off} , which is scaled (somewhat arbitrarily) to inlet diameter. The value suggested is that frequency at which a truncated input variance is 95 percent of that computed for the highest frequency used in the definition of the inlet response functions (a better cutoff frequency could be developed by CFD analysis).

The conditional unstart probability in eq. (3) is now given terms of A_y as (Barry, 1973)

$$P(y|E) = \int_0^\infty p(\sigma_i) e^{-\frac{1}{2} \left(\frac{y}{A_y \sigma_i} \right)^2} d\sigma_i \quad (12)$$

where $p(\sigma_i)$ is the probability density of σ_i , i.e., of the input disturbance "intensity."

Equations (11) and (12) thus identify the disturbance input spectra, and output throat Mach number and shock position spectra, as necessary to calculate conditional probabilities of disturbance unstart due to continuous, random, free-stream disturbances. They also indicate that these conditional probabilities are *inlet specific*; *this precludes a general description of the global distribution of conditional unstart probability*, like those given for the prior disturbance encounter probabilities in Figs. 3.3-1.

Finally, because it is based on a more realistic representation of the nature of the disturbed natural environment, the continuous disturbance approach to unstart probability analysis is the preferred approach (Barry, 1973).

4.3 Summary

Separate equations are given for calculating conditional unstart probabilities from throat choking or from the shock moving to the throat, which are based on descriptions of the disturbed environment in terms either of discrete or of continuous disturbances. The discrete disturbance equation is well suited to the analysis of inlet unstart due to a singular event, such as an encounter with an airplane wake; but the continuous disturbance equation is preferred for inlet unstart probability analysis for the naturally disturbed environment.

The equations show the conditional unstart probabilities to be inlet specific. This precludes a general description of the global distribution of conditional unstart probability, as for the case of the prior disturbance encounter probability.

5.0 Disturbance Spectra

5.1 Atmospheric Disturbance Scales

Atmospheric disturbances come in all sizes, from the "macroscale" (conventionally, horizontal scales in the size range of a few hundred km), through the "mesoscale" (scales from a few tens to a few hundreds of km), to the "microscale" (tens of km to cm). "Horizontal scale" in these conventions is taken as the distance over which wind speed changes by an amount comparable to the magnitude of the wind speed itself. For example, if the wind flow consists of closed circulations or "eddies," the horizontal scale is then considered the radius of a typical eddy (this scales disturbances too, in the atmospheric state parameters, cf. Section 3.1). Macroscale disturbances are

the day-to-day weather changes that are readily resolved by the synoptic weather observation network. Mesoscale includes the narrower jet streams, mountain waves, and convective storms. They require special observation networks or techniques for experimental study. Microscale disturbances are in the realm of true 3-D turbulence.

5.2 Spectrum Analysis

For HSCT inlet unstart analysis, a statistical description of a random mix of disturbances of all scales starts with the one-dimensional disturbance covariance function along an HSCT flight track

$$M_{ij}(\xi) = \langle D_i(x) D_j(x + \xi) \rangle \quad (14)$$

where x is position on the track, ξ is a displacement along the track, and the brackets denote an average of the product of disturbances D_i and D_j at the different track locations. The spectrum function is the Fourier transform of $M_{ij}(\xi)$

$$S_{ij}(k) = \int_{-\infty}^{\infty} M_{ij}(\xi) e^{-i2\pi k\xi} d\xi \quad (15)$$

where k is a spatial frequency now, or wavenumber, in cycles per unit length, usually cycles per meter. For $i=j$ eq.(14) is an autocovariance and eq.(15) is the power spectral density; for $i \neq j$ eq.(14) is a cross covariance and eq.(15) is a cross spectrum. The PSD and cross spectrum functions provide the distributions of the disturbance variance and covariance with wavenumber, respectively. The PSD is defined such that the complete mean square amplitude (cf. eq. (11)), i.e., the disturbance intensity, is

$$\sigma_i^2 = \int_0^{\infty} S_{ii}(k) dk \quad (16)$$

If locations and displacements are measured in time rather than one-dimensional space, the wavenumber spectrum can be converted to a frequency

spectrum as discussed earlier using

$$f = k U \quad (17)$$

where U is the HSCT true air speed. In this context, wavenumber k is akin to the "reduced frequency" used in descriptions of turbulence for gust loads analyses (e.g., Rustenburg, 1991).

5.3 Disturbance Power Spectral Densities

5.3.1 Measured Power Spectral Densities

5.3.1.1 Global Atmospheric Sampling Program (GASP) Data

Shown in Fig. 5.3-1 (Nastrom and Gage, 1985) are power spectra of meridional (north-south) and zonal (east-west) upper air wind speeds; and of potential temperature, θ . This is the temperature a parcel of dry air would have if brought adiabatically from its initial state to a pressure of 1000 hectopascals (hPa, equal to millibars); i.e.,

$$\theta = T \left(\frac{1000}{p} \right)^{0.288} \quad (18)$$

where T is the temperature ($^{\circ}\text{K}$) at pressure p (hPa); the exponent is the ratio of the dry air gas constant to the specific heat at constant pressure. Potential temperature is conserved during adiabatic changes in the atmosphere.

The spectra shown in Fig. 5.3-1 are as comprehensive a set as is available to characterize mesoscale atmospheric disturbances in the upper atmosphere. They were calculated from data acquired over a four year time period (1975-1979) during the Global Atmospheric Sampling Program (GASP). This was a NASA program to gather data on minor atmospheric constituents and meteorological variables near the tropopause (Perkins, 1976; Papathakos and Briehl, 1981). Specially instrumented B747 airplanes in routine

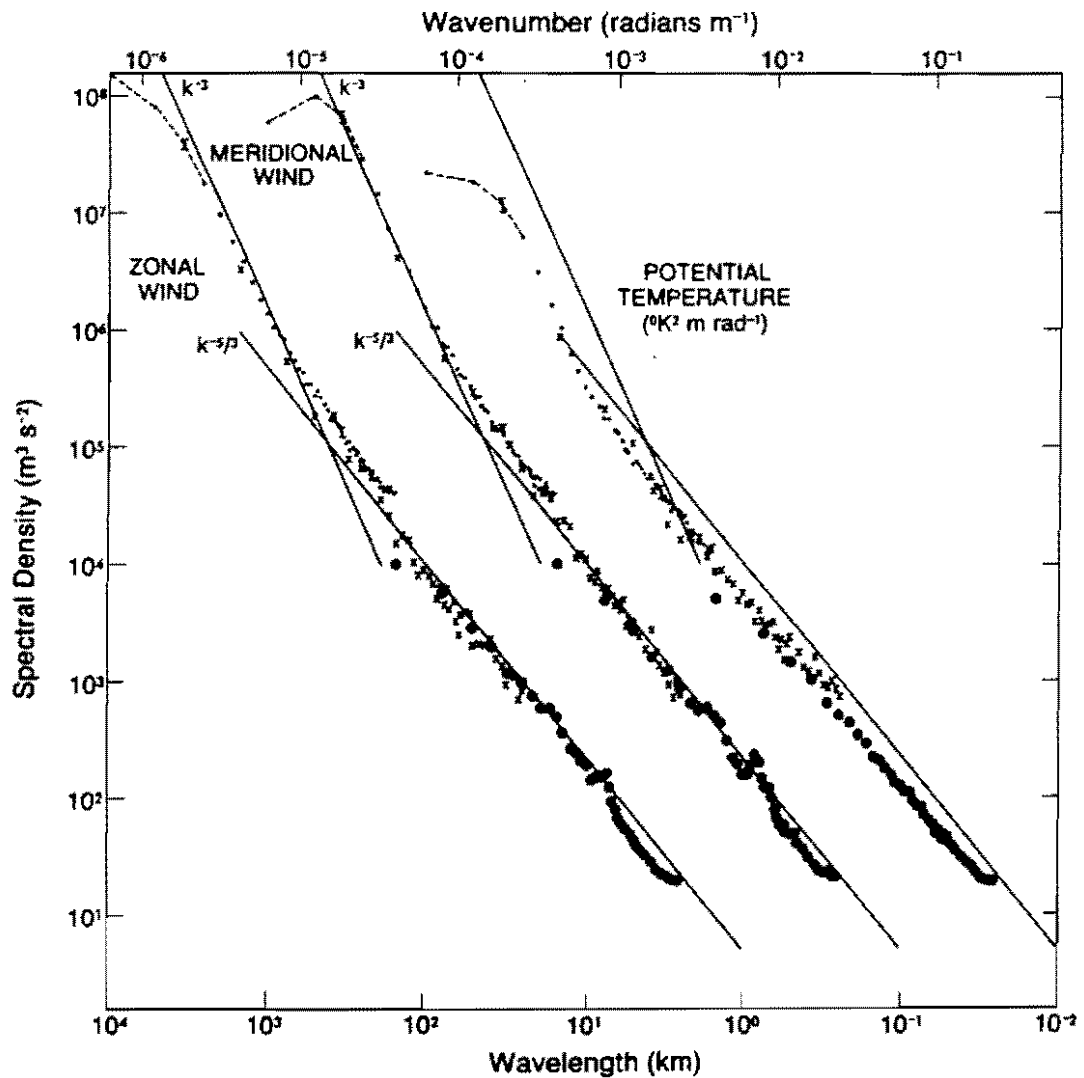


Fig. 5.3-1. Upper troposphere and lower stratosphere mesoscale power spectral densities of horizontal wind components and potential temperature; the spectra for meridional wind and temperature are shifted one and two decades to the right for clarity (Nastrom and Gage, 1985, courtesy of the American Meteorological Society). Ordinate values are spectral densities relative to angular wavenumber; for values relative to cyclic wavenumber, multiply by 2π .

commercial service were used to gather the data.

The plots in Fig. 5.3-1 are of spectral density along the ordinate (units $(\text{m/sec})^2/\text{rad/m}$ for wind speed, and $^\circ\text{K}^2/\text{rad/m}$ for temperature), versus angular wavenumber (rad/m) along the upper abscissa, and disturbance scale size (km) along the lower abscissa. As for temperature, the units for the wind speed PSD's are stated here for angular rather than cyclic wavenumber as implied by the ordinate label. The relationship between cyclic and angular wavenumber spectral densities is $S(k) = 2\pi S(\Omega)$.

There are over 6900 flights in the GASP data set, made during all seasons and covering a wide variety of latitudes and longitudes. The geographical distribution of the GASP observations is shown in Fig. 5.3-2. Most measurements were at altitudes between 9 and 14 km. The nominal sample interval was about 75 km along the flight path; but on 97 selected flights, data were recorded at about 1 km intervals. This allowed spectral analysis of the GASP data over a range of scales from a few to nearly 10,000 km. The plots in Fig. 5.3-1 are the average for all flights of the spectral components at each disturbance wavelength (wavenumber).

Note that the spectra are well approximated by an inverse power law

$$S_{ij} = A_i k^{-m} \quad (19)$$

which, in logarithmic coordinates with $S_{ij}(k)$ as the independent variable plots as a straight line with slope $-m$ and intercept $\log(A_i)$. The straight line in Fig. 5.3-1 is with slope $-m = -5/3$.

5.3.1.2 Stratospheric Balloon Data

Shown in Fig. 5.3-3 are examples of PSD's of stratospheric CAT (Barat, 1982), calculated from records of horizontal wind speed measured with a sensitive anemometer suspended 150 m beneath a constant pressure

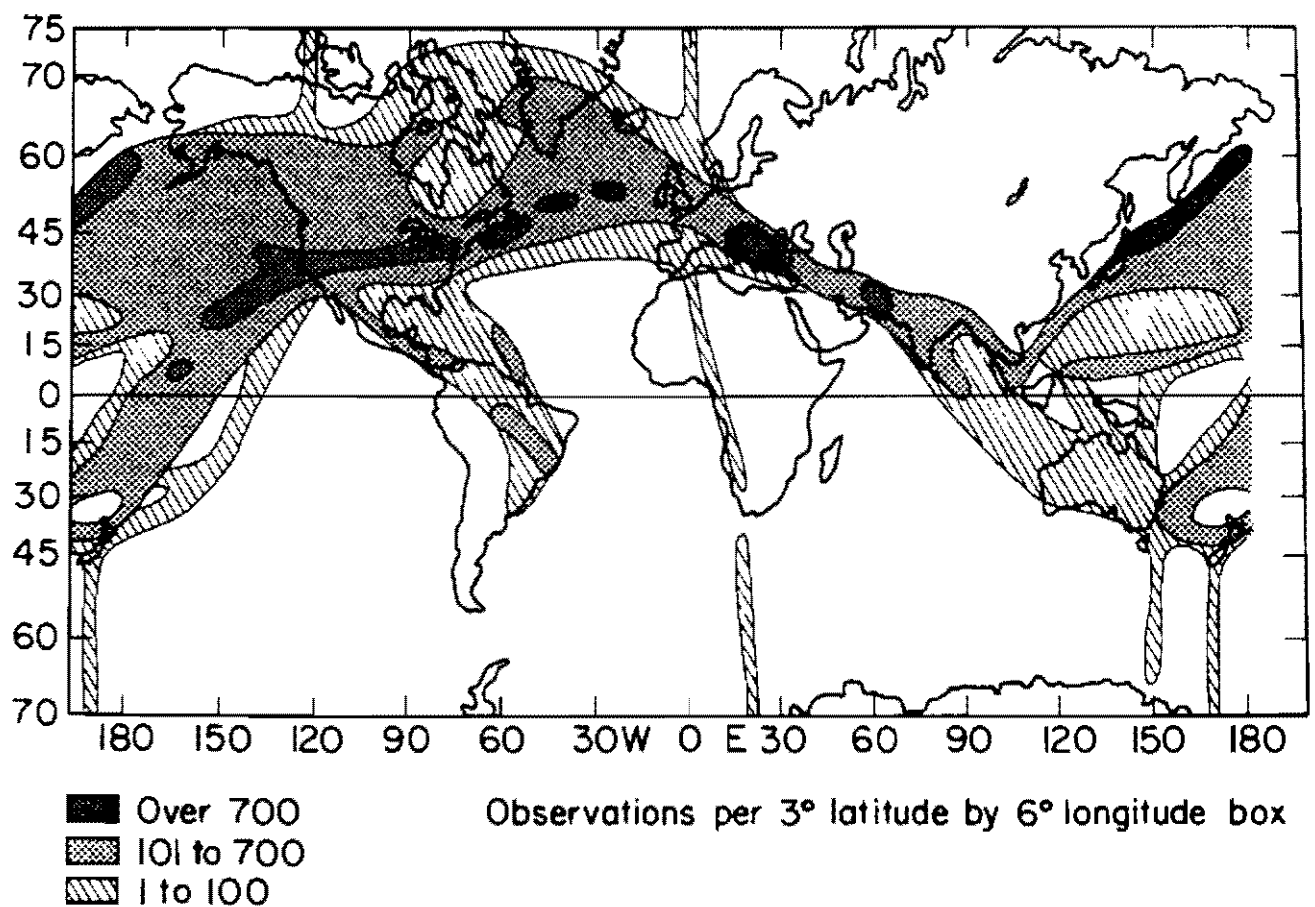


Fig. 5.3-2. Geographical distribution of GASP observations (Nastrom and Gage, 1985, courtesy of the American Meteorological Society).

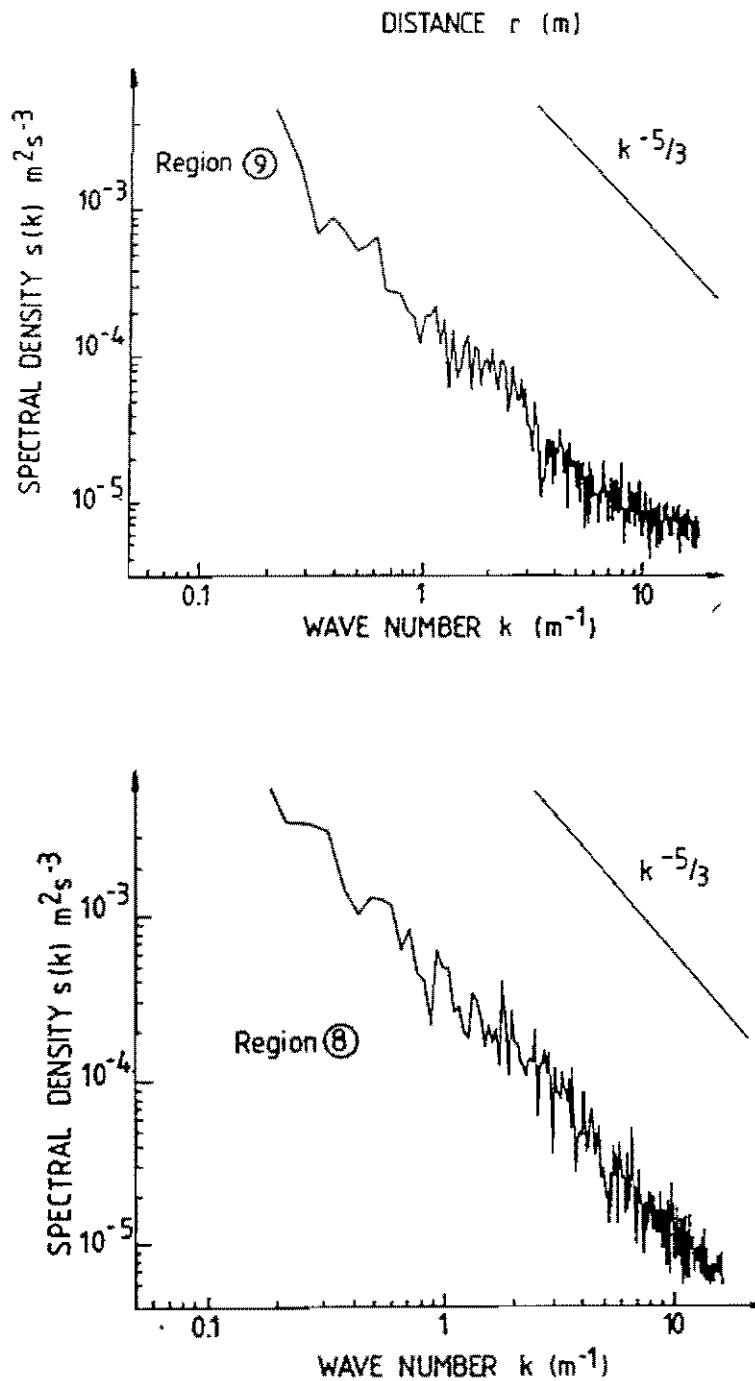


Fig. 5.3-3. Microscale power spectral densities of longitudinal wind speed. The spectra are from wind speeds measured via balloon-borne sensors in the middle stratosphere (Barat, 1982, courtesy of the American Meteorological Society). Units along the ordinates are incorrectly given. They should read m^3s^{-2} .

balloon. Data were collected over southern France near the Spanish border, at an altitude of nearly 27 km. Note that scales of motion here are truly microscale, in the wavelength range of some meters down to some tens of centimeters. Again multiply ordinate values by 2π to obtain $S(k)$.

Note that these PSD's begin some three decades in wavenumber beyond where the GASP spectra end; but note once more the good agreement with the $-5/3$ power law spectral representation. This same spectral behavior was noted by Cadet (1977) in results from similar balloon experiments over South Africa. A further finding of these balloon experiments is that microscale CAT occurs intermittently in layers of limited thickness.

5.3.1.3 ER-2 Data

The ER-2 meteorological data obtained during the STEP Tropical, AAOE, and AASE experiments (cf. Section 1.2.2) were analyzed in the hopes of obtaining power spectra over scales intermediate to those of the GASP and the balloon spectra. Power spectra for the longitudinal (along the flight track), lateral, and vertical wind components, and for temperature and pressure, were calculated for 84 flight track segments. Flight segments were chosen to be straight and level flight, with no missing data. Flight altitudes were generally in the range from 16 to 21 km.

Twenty-four PSD's were calculated from the STEP Tropical data, 18 from the AAOE data, and 42 from the AASE data. Mean values and slowly varying trends were first removed from the raw data, and a discrete Fourier transform method was then applied to compute complex spectra from the residuals (Rabiner, et al, 1979). Typical PSD plots are shown in Fig. 5.3-4. The spectra typically show a generally flat portion at low wavenumbers, a more steeply sloped intermediate section, and then a flatter portion at high wavenumbers. The flat low frequency portion is an artifact of the detrending technique (cubic polynomial) used to preprocess the data. The intermediate portion reflects the true nature of the disturbed atmosphere; but the flatter high wavenumber portions of the spectra, with an average slope of about -1.0 , look more like random instrument noise.

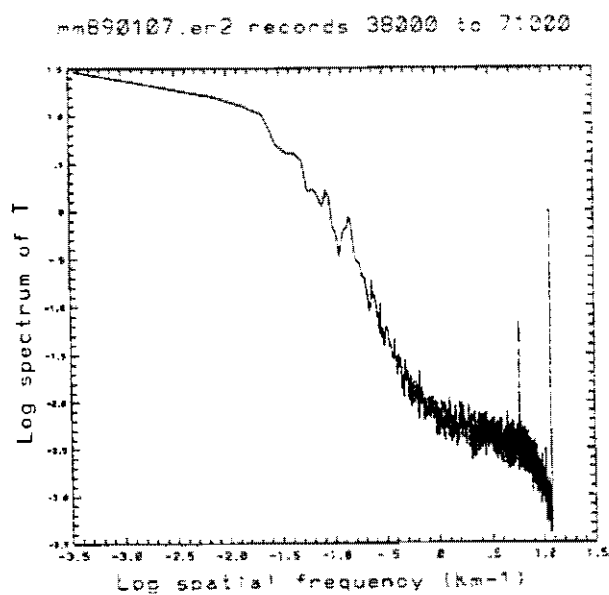
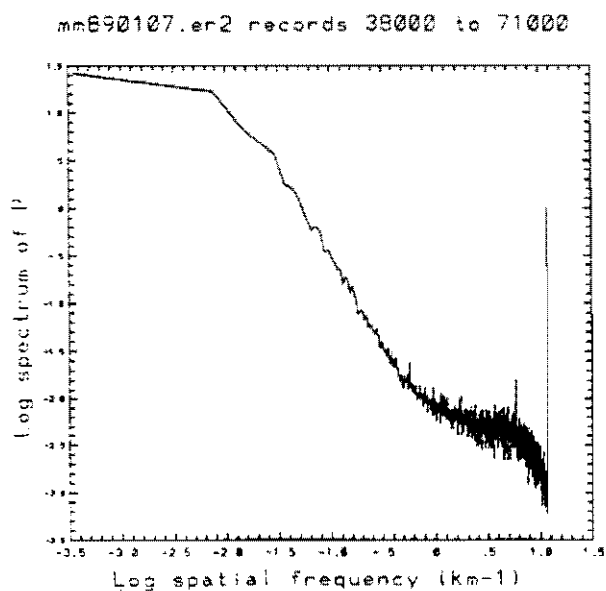
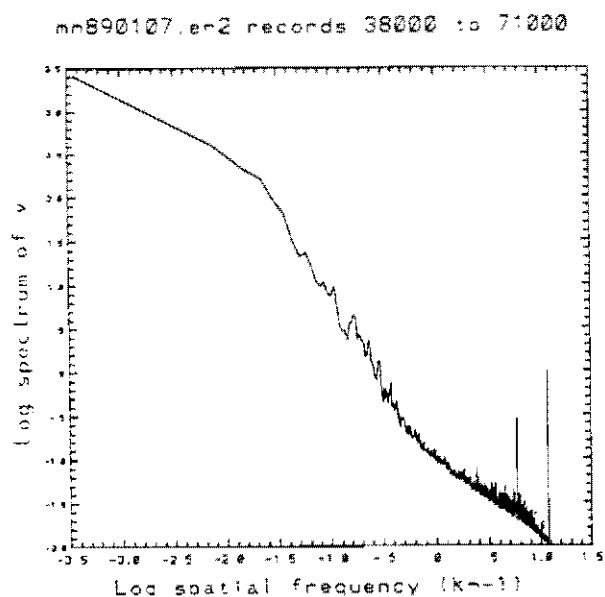
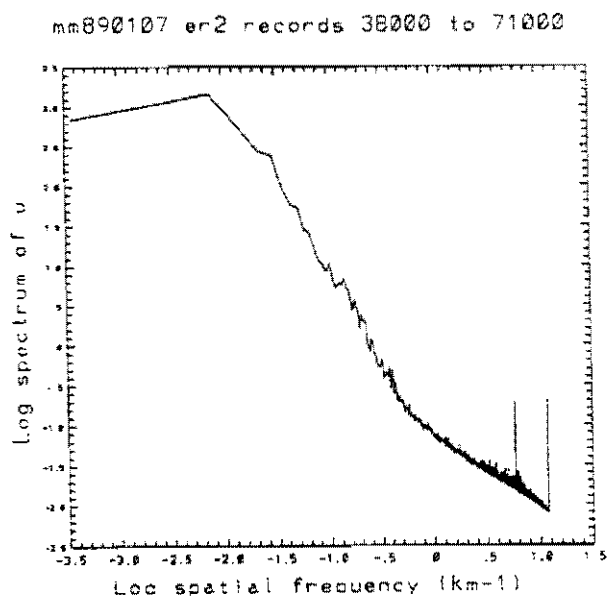


Fig. 5.3-4. Representative variance spectra calculated from ER-2 data obtained during the AAOE, the AASE, and the STEP Tropical experiments.

The performance specifications for the MMS used to acquire the data (0.5 sec instrument time constant, 5 Hz sampling rate) indicate that good spectral estimates should have been possible down to spatial scales less than 100 meters (2.5 Hz Nyquist frequency with a flight speed of about 200 m/sec). However, Murphy (1989) confirms that beyond a wavenumber of about 1 km^{-1} , MMS spectra do reflect as yet unexplained noise in the data, rather than the true nature of the disturbed atmosphere.

In the intermediate portion of the spectra where shape is determined by atmospheric structure, spectral slopes from the 84 flight track segments range between the $-5/3$ value noted previously, and -2.0 , with an average of about -1.9 .

5.3.2 Power Spectral Density Models

5.3.2.1 Microscale Spectra

The $-5/3$ power law for the PSD is most often cited in relation to the Kolmogoroff spectrum for continuous, 3-D, isotropic turbulence in the inertial subrange of microscale turbulent motions. In this range it is assumed that the kinetic energy of turbulent motion per unit mass is neither lost nor gained, but simply transported across each wavenumber toward increasing wavenumbers at a constant rate, ϵ . This down-scale energy transport rate is termed the eddy dissipation rate, and has dimensions of energy per unit mass per unit time (usually $\text{m}^2/\text{sec}^2/\text{sec}$). With the constraint of constant kinetic energy, similarity theory dictates the following for the one-dimensional power spectrum for component wind speeds in the inertial subrange (Lumley and Panofsky, 1964)

$$S_{ii}(k) = \alpha_i \epsilon^{2/3} k^{-5/3} \quad (20)$$

where here, referring to eq. (19), $A_i = \alpha_i \epsilon^{2/3}$ with α_i a dimensionless, universal constant. This is the spectrum shown in Fig. 5.3-3.

5.3.2.2 Mesoscale Spectra

The assumption of 3-D isotropy required for the derivation of eq. (20) is clearly not valid for random mesoscale motions; rather, observations show that in a stably stratified atmosphere (negative buoyancy force on vertically displaced air parcels), these motions take on a quasi two-dimensional structure, with isotropy in only two dimensions in thin layers (Lilly, 1983). For this to happen, Kraichnan (1967) notes that mean square vorticity as well as kinetic energy must be an inviscid constant of mesoscale disturbed flow.

The result of this additional constraint means that in contrast to the predominantly one-way flow of kinetic energy in 3-D turbulence, a down scale energy transfer to higher wavenumbers in 2-D turbulence must be accompanied by a comparable up scale transfer to lower wavenumbers. The PSD that results from this latter "reverse flow" of kinetic energy is again a power law with $k^{-5/3}$; but with a coefficient that is proportional to an energy insertion rate rather than an energy dissipation rate (Kraichnan, 1967),

$$S_{ii}(k) = C \left(\frac{dE}{dt} \right)^{2/3} k^{-5/3} \quad (21)$$

Note then, that a theoretical $-5/3$ power law applies to power spectra for quasi-horizontal as well as 3-D atmospheric disturbances, out to a disturbance wavelength of at least 400 km (the -3 power law behavior at still longer wavelengths can be argued separately) (Gage, 1950). This is the spectrum that describes the data in Fig. 5.3-1 for disturbance wavelengths less than 400 km. Its shape is that of the semi-empirical von Karman power spectrum (Rustenburg, 1991).

Lilly (1983) points out, however, that sporadic forcing of the environment by mesoscale energy sources leads to a patchy disturbed environment with a slightly different spectrum. Specifically, spectrum coefficients adjust in proportion to the separation, λ , between individual disturbance patches along a flight track; and the wavenumber exponent decreases from $-5/3$ to -2 ,

$$S_{ii}(k) = \frac{C'}{\lambda^{1/3}} \left(\frac{dE}{dt} \right)^{2/3} k^{-2} \quad (22)$$

This is close to the shape of the ER-2 spectra shown in Fig. 5.3-4. It is also the shape of the semi-empirical Dryden disturbance spectrum (Rustenburg, 1991).

It is worth noting that the 74 km sample interval used to acquire most of the GASP data would tend to smooth out the effect of patchy disturbance encounters in the spectral estimates shown in Fig. 5.3-1; and patchiness is ignored in the spectra shown in Fig. 5.3-3, i.e., these spectral estimates are conditional on a *bona fide* CAT encounter. Thus, due to the specific experimental procedures, the data from the GASP and balloon investigations should be compared to the -5/3 power law, while the ER-2 spectra should be compared to Lilly's -2.0 law.

5.3.2.3 The Complete Spectrum

Gage (1979) postulates that up scale energy transport is the explanation for the $k^{-5/3}$ behavior of the GASP spectra. He further suggests that energy cascade in both directions *from a mesoscale energy source* (i.e., jet stream wind shear, gravity waves, thunderstorms, cf. Section 3.1.2.1) would yield a one-dimensional spectrum that transitions smoothly from one consistent with 2-D turbulence theory at low wavenumbers, to one consistent with 3-D turbulence theory at high wavenumbers. Lilly (1983) presents the same sort of picture, viz., that of a continuous spectrum from mesoscale forcing, with no "gaps" in the spectrum across the transition from mesoscale to microscale wavenumbers. The composite plot in Fig. 5.3-5 of Figs. 5.3-1 and 5.3-3, supports this idea.

The fact that the complete component wind speed PSD can be represented as continuous across the meso- and microscale ranges is important, because it means that even though the 2-D disturbance PSD is not the result of the exact "first principles" physics of 3-D turbulence, *it behaves as if it was*. Thus, with a continuous -5/3 power law as a common

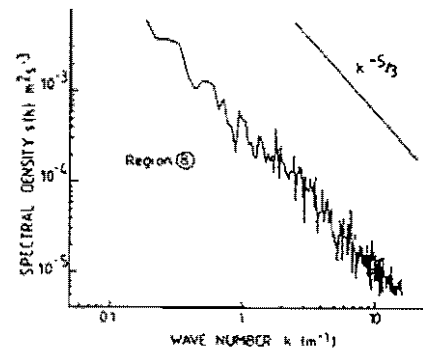
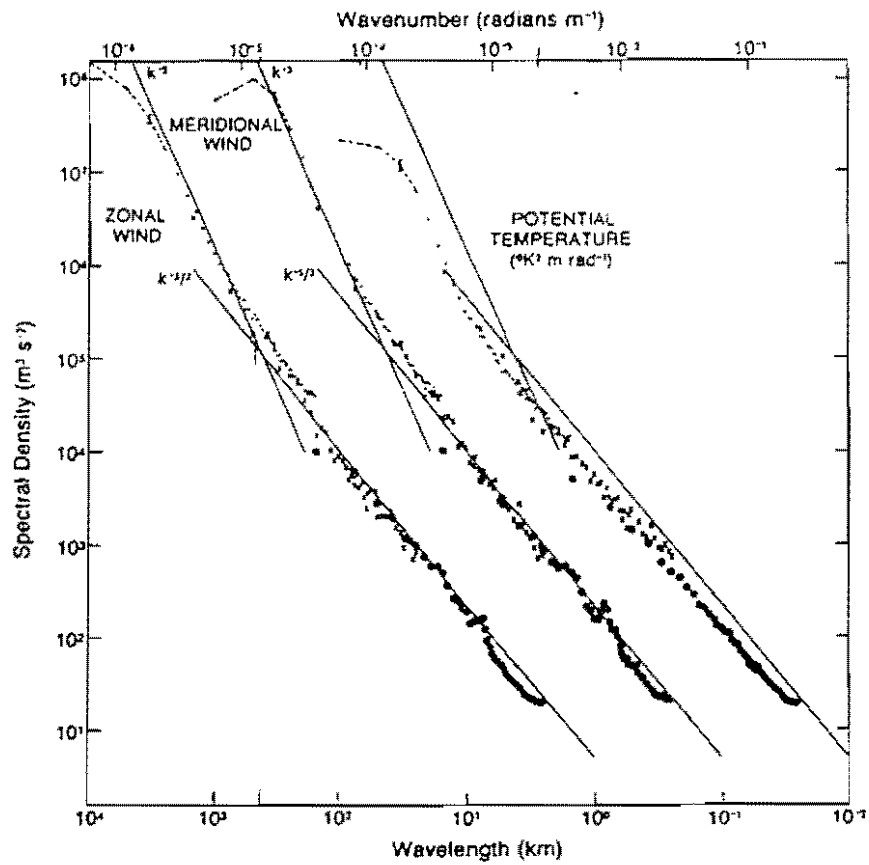


Fig. 5.3-5. Composite plot of the meso- and microscale wind speed power spectral densities shown in Figs. 5.3-1 and 5.3-3.

shape, the complete component wind speed PSD can be parameterized according to eq. (20) by the single physical quantity, the eddy dissipation rate, ϵ . For isentropic changes of state, and assuming temperature disturbance decay rates that are in proportion to ϵ , this same result carries over to the temperature and pressure PSD's. Equation (19) thus emerges as the generic PSD equation for all free-stream variables that affect inlet unstart. The equations for the separate disturbance types differ from each other only in the coefficient $A_i = a_i \epsilon^{2/3}$, say, as given in Table 5.3-1, all of which are expressed in terms of ϵ . For component wind speeds the numerical parts of the coefficients, a_i , are dimensionless; for the temperature and pressure PSD's they are dimensioned with units $^\circ\text{K}^2\text{sec}^2/\text{m}^2$ and $\text{hPa}^2\text{sec}^2/\text{m}^2$, respectively. Equation (19) with the A_i 's as given in Table 5.3-1 constitute the PSD models for inlet unstart analysis.

5.4 Disturbance Cross Spectra

Disturbance cross covariances are not well-behaved like auto-covariances. They are not necessarily even or odd, and so are usually written as the sum of separate even and odd parts

$$M_{ij}(\xi) = E_{ij}(\xi) + O_{ij}(\xi) \quad (23)$$

The Fourier transform of eq.(23) thus yields a cross spectral density with real and imaginary parts

$$S_{ij}(k) = \text{Co}_{ij}(k) + iQ_{ij}(k) \quad (24)$$

where Co_{ij} is called the cospectrum and Q_{ij} the quadrature spectrum (Lumley and Panofsky, 1964). The cospectrum gives the distribution with wavenumber, of the cross covariances between disturbances i and j ; the quadrature spectrum is a measure of the cross correlation between the two. It is zero for M_{ij} even (i.e., for M_{ij} symmetric in ξ).

No generalities can be made regarding cross spectral densities. They admit to negative values, and spectral shape depends not only on which two

Table 5.3-1. Coefficients for the generic power spectral density function

<u>Parameter</u>	<u>Coefficient A_i</u>
Longitudinal gust speed	$0.15 \epsilon^{2/3}$
Crosswind gust speed	$0.20 \epsilon^{2/3}$
Vertical gust speed	$0.20 \epsilon^{2/3}$
Vector wind speed	$0.35 \epsilon^{2/3}$
Temperature	$0.39 \epsilon^{2/3}$
Pressure	$0.0005 (p_o / T_o)^2 \epsilon^{2/3}$

Note: For component wind speeds the numerical parts of A_i are dimensionless; for temperature and pressure they are dimensioned with units $^{\circ}\text{K}^2\text{sec}^2\text{m}^{-2}$ and $\text{hPa}^2\text{sec}^2\text{m}^{-2}$, respectively, for T_o in $^{\circ}\text{K}$, P_o in hPa , and ϵ in $\text{m}^2\text{sec}^{-3}$.

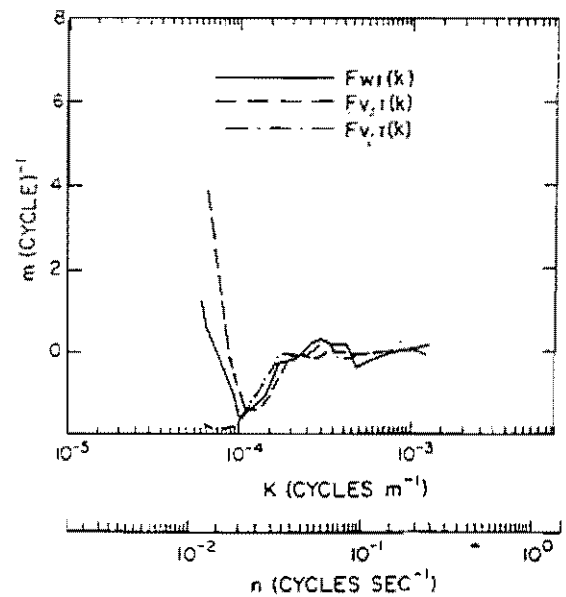
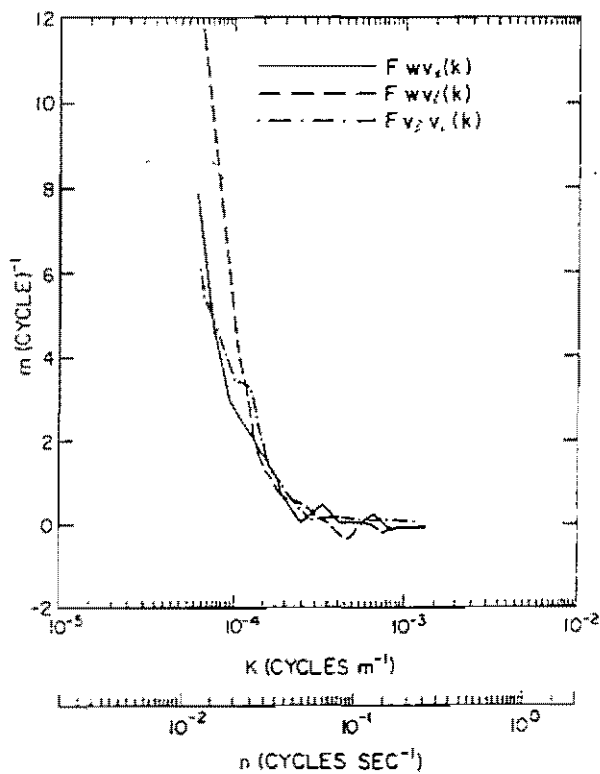
disturbances are selected for analysis; but also on how those disturbances are cross correlated. This cross correlation, moreover, can change with weather on a day-to-day basis. The non-standard nature of cross spectra is to be seen in the plots of cospectra between various disturbance types in Figs. 5.4-1a and 5.4-1b. The cospectra in Fig. 5.4-1a were calculated by Kao and Gebhard (1971) from HICAT data obtained over southwestern U. S. at altitudes ranging from 15.7 to 18.2 km. Those in Fig. 5.4-1b were calculated from ER-2 data obtained during the STEP Tropical experiment.

The comparison of Figs. 5.4-1a and 5.4-1b is intended to show that the only point of similarity in the two sets of data is the tendency for the spectra to approach zero at wavenumbers of order a few tenths km^{-1} , or for wavelengths of several km. The same sort of behavior is seen in cross spectra computed by Kennedy and Shapiro (1980) from data obtained in the upper troposphere. This approach to zero is at about the start of the microscale range of disturbances, wherein the assumption of 3-D isotropy holds. Theory says that cross spectra are zero under this condition.

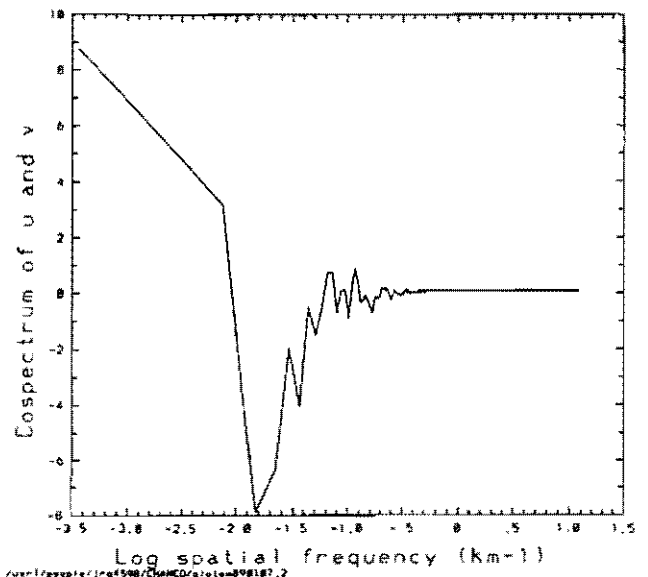
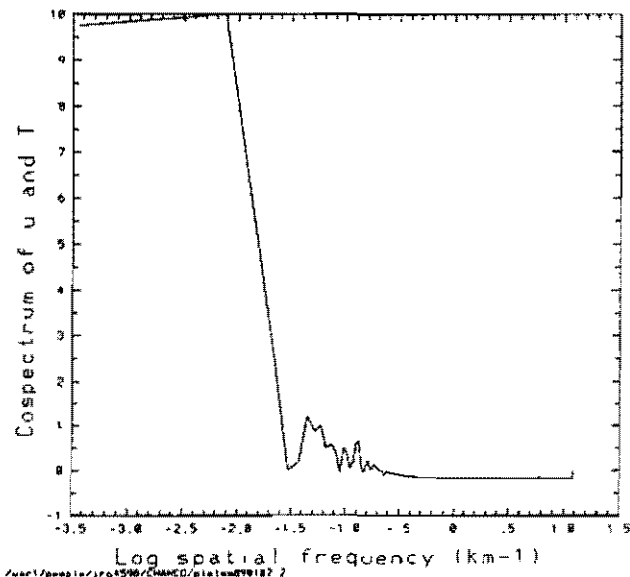
This is important because during supersonic cruise, disturbance wavenumbers of a few tenths km^{-1} translate to disturbance encounter frequencies of several tenths Hz. These are expected to be well within the response capability of control loops. In other words, cross spectral densities need not be considered in inlet unstart analysis. This was anticipated in Section 4.1.2. Thus with just disturbance PSD's needed for this analysis, *the climate of the eddy dissipation rate alone establishes the climate of the inlet-specific, conditional unstart probability as given by eq. (12).*

5.5 Summary

Experimental data confirm theoretical disturbance PSD models that are parameterized in terms of a single atmospheric variable, the eddy dissipation rate, ϵ . At the same time it was demonstrated that disturbance cross spectral densities can be neglected in calculating inlet unstart probabilities. This means that the climate of the eddy dissipation rate alone, establishes the climate of the inlet-specific, conditional unstart probability.



a.) Early mid-latitude NASA U-2 data



b.) Recent high latitude ER-2 data

Fig. 5.4-1 Cross spectra between component wind speeds, and between wind speeds and temperature as calculated from a.) early NASA U-2 mid-latitude turbulence research flights (Kao and Gebhard, 1971); and from b.) recent ER-2 data from NOAA stratospheric ozone research flights.

6.0 Eddy Dissipation Rate Climate

6.1 Dissipation Rate Database

Given the universal PSD shape, the eddy dissipation rate can be calculated from the PSD in several ways. The first is simply to solve the generic spectrum equation for ϵ , and then calculate ϵ from a single, measured spectral component at arbitrary wavenumber, k_c , mesoscale or microscale. For the vector wind speed the calculation would be according to

$$\epsilon = \left[\frac{S_{vv}(k_c)}{a_i} \right]^{3/2} k_c^{5/2} \quad (25)$$

where $S_{ij}(k_c)$ is the spectral density at the arbitrary wavenumber.

Barat (1982) used this approach to calculate ϵ from longitudinal wind speed data from his balloon experiment (cf. Section 5.3.1.2). For two encounters with CAT at an altitude of nearly 27 km over southern France, he calculated

$$\begin{aligned} \epsilon &= 2.8 \times 10^{-5} \pm 0.4 \times 10^{-5} \quad \text{m}^2 \text{sec}^{-3} \\ \epsilon &= 1.4 \times 10^{-5} \pm 0.2 \times 10^{-5} \quad \text{m}^2 \text{sec}^{-3} \end{aligned}$$

From a similar experiment at an altitude of about 12 km over mountainous terrain in South Africa, Cadet (1977) found a mean ϵ for 20 CAT records of

$$\langle \epsilon \rangle = 2.75 \times 10^{-5} \quad \text{m}^2 \text{sec}^{-2}$$

with about a three order of magnitude range

$$0.1 \times 10^{-5} \leq \epsilon \leq 20.0 \times 10^{-5} \quad \text{m}^2 \text{sec}^{-3}$$

Carrying the use of the variance spectrum for calculating ϵ one step farther, the next simplest approach is to first integrate the spectrum equation from k_c to infinity and then solve for ϵ ,

$$\epsilon = k_c \left[\frac{2}{3} \frac{\sigma_c^2}{a_i} \right]^{3/2} \quad (26)$$

where σ_c^2 is the variance under the spectrum curve from wavenumber k_c over all remaining, higher wavenumbers (for CAT *per se*, if k_c is defined by the so-called "outer scale of turbulence," then σ_c^2 is the turbulence intensity).

Lilly, et al (1974) used this approach to calculate ϵ from HICAT flight data. Their findings for mean ϵ when stratified by underlying terrain type were in the range

$$6.3 \times 10^{-4} \leq \langle \epsilon \rangle \leq 16.8 \times 10^{-4} \text{ m}^2 \text{ sec}^{-3}$$

with the low value being associated with flights in CAT over water or flatland; and the high value with flights over high mountains. Note that these values are an order of magnitude higher than those cited previously; but the HICAT data were from studies with the inherent objective of searching out regions of strong turbulence, in clouds as well as clear air; hence the bias toward high values.

The final approach to calculating ϵ from disturbance variance spectra is to integrate the spectrum equation over a wavenumber band from k_{lo} to k_{hi} say, to give ϵ in terms of the partial variance within the band; i.e.,

$$\epsilon = \left[\frac{2}{3} \frac{(\Delta\sigma^2)}{a_i (k_{lo}^{-2/3} - k_{hi}^{-2/3})} \right]^{3/2} \quad (27)$$

where $(\Delta\sigma^2)$ is the partial in-band variance between the low and high

wavenumber band limits, k_{lo} and k_{hi} , respectively. Nastrom and Gage (1985) calculated in-band variances for all GASP wind speed spectra in the 12.5 - 25 km wavelength band. The calculations were stratified according to the type of underlying terrain, latitude, and season. These data for stratospheric spectra, when processed for ϵ according to eq. (27), yield the stratified ϵ -data shown in Table 6.1-1.

6.2 Climatological Extrapolation

The development of the eddy dissipation rate climate again requires extensive extrapolation of data either from areas outside the HSCT route structure, or from altitudes below the supersonic cruise altitude. Factors to consider in the extrapolation include the influence of terrain roughness on enhanced ϵ due to breaking gravity waves in the upper atmosphere; and systematic variations of ϵ with altitude, latitude, and season. These factors are discussed in order.

6.2.1 Terrain Effects

Enhanced ϵ at HSCT cruise altitudes due to topographically induced mountain waves can be expected off shore of continental land masses, and in the vicinity of isolated ocean islands. This is according to the well-documented increase of disturbance intensity *per se* over rough terrain. Vinnichenko, et al (1973) reported that USSR supersonic flights in the altitude range 9 to 18 km had a mean maximum gust acceleration over mountains 3 times the average for flights over plains. Similarly, Coldscan RB-57 flights had about 3 times the number of reports of "moderate" turbulence over mountains than over water (MacPherson and Morrissey, 1969). Lilly, *et al* (1974), found that both the intensity and frequency of stratospheric turbulence is "strongly controlled" (sic) by underlying terrain. Their data indicate ϵ -values over mountains over 2.5 times those over water. This factor increases to over 5 in the GASP data (Table 6.1-1).

The same sort of "terrain effect" may be expected from breaking gravity waves over thunderstorms (cf. Section 3.2.3). The STEP Tropical

Table 6.1-1. Annual mean lower stratosphere eddy dissipation rate by group

<u>Stratification Group</u>	<u><ε></u>	<u>Variability</u>
Over ocean	1.46 E -5	} Factor of 5.3 variation
Over flatland	2.35	
Over mountains	7.76	
Global mean	2.00	
> 60 N latitude	0.93	} Factor of 2.3 variation
45 N - 60 N	1.86	
30 N - 45 N	2.30	
15 N - 30 N	1.37	
Winter	2.11	} Factor of 4.0 variation
Spring	2.09	
Summer	5.32	
Autumn	1.40	

Note: Eddy dissipation rates are in units $\text{m}^2\text{sec}^{-3}$. Lack of data does not permit stratification by latitude in the Southern Hemisphere.

experiment included ER-2 overflights of large thunderstorms in the ITCZ, which commonly extend to heights above 20 km. An anecdotal piece of information from one such flight just above the anvil (cirrus shield) from a vigorous thunderstorm included the remark, "... a rising turret apparently buffeted the ER-2, creating severe turbulence and large amplitude oscillations of the wings." This prompted the remark from the ER-2 pilot in response to the suggestion for another such flight, "Never again." (Ref. Gaines and Hippskind, 1988).

6.2.2 Altitude Effects

Except in the immediate vicinity of tropopause jet streams, eddy dissipation rates decrease modestly with altitude in the stratosphere. The data in Section 6.1 (from the GASP and the balloon experiments) indicate only about a factor of two decrease in mean ϵ from lower to middle stratospheric levels. The exception is near the tropopause, when Kelvin-Helmholtz waves induced by strong jet stream wind shear amplify and break to cause CAT (Wallace and Hobbs, 1977). These breaking waves are sometimes marked by "billow clouds," the counterparts of the lenticular clouds of standing gravity waves. The data in Section 6.1 from Lilly, *et al* (1974), indicate jet stream CAT can result in ϵ -values an order of magnitude above mean levels.

Still, *intralevel* variations in ϵ about the mean value are much greater than the *interlevel* variation of the mean value itself. The cumulative distributions of meridional and zonal wind speed spectral densities at wavenumber $k = 0.0025 \text{ km}^{-1}$ calculated from GASP data by Gage and Nastrom (1985) (cf. Section 6.4), imply that about a three order-of-magnitude range in ϵ can be expected at any altitude in the lower stratosphere.

6.2.3 Latitude Effects

The latitudinal variation of stratospheric eddy dissipation rates in the Northern hemisphere is as indicated in Table 6.1-1. Maximum values are found in mid-latitudes, coincident with the mid-latitude maximum in storm activity; lesser values are found over polar and tropical regions. However, the total variation is about a factor of three, with minimum ϵ -values at high

latitudes. This behavior is also expected in the Southern hemisphere.

6.2.4 Seasonal Effects

Maximum ϵ occurs during summer in the stratosphere, but during winter in the upper troposphere. A possible explanation is that storms as such are more frequent in winter, but the vigorous convection that results in thunderstorms penetrating the tropopause to the mid stratosphere, is more frequent in summer. At any rate, the seasonal variation in mean stratospheric ϵ is about a factor of two about the annual mean value.

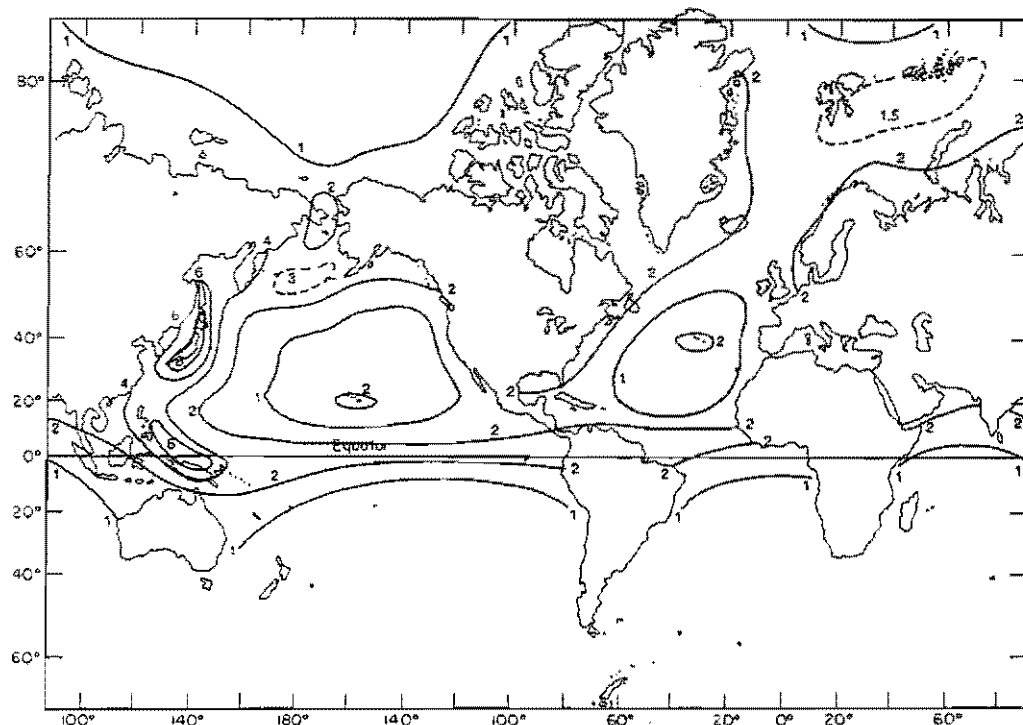
6.3 Global Distribution of the Eddy Dissipation Rate

Shown in Fig. 6.3-1 (upper panel) is the global distribution of annual mean eddy dissipation rate. This again represents due consideration in combination, of all the factors listed in Section 6.2 that might influence the extrapolation of ϵ to the areas and altitudes dictated by the HSCT route structure (lower panel).

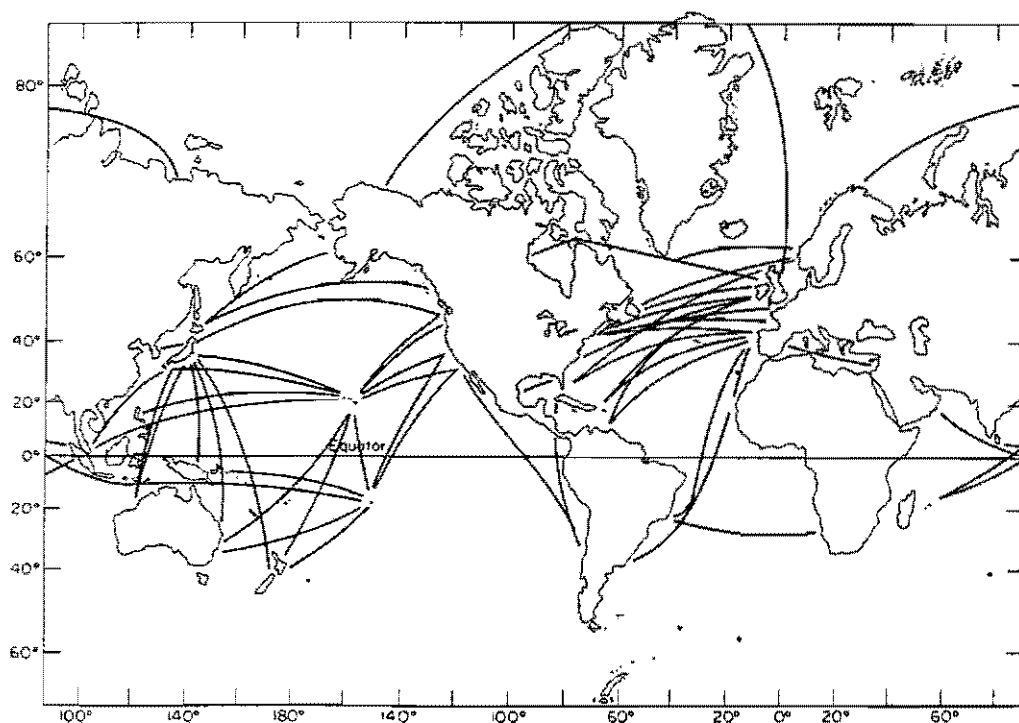
The pattern in the distribution of ϵ reflects those seen in the global distributions of disturbance encounter probabilities (Fig. 3.3-1). This is so because the factors that affect the frequency-of-occurrence of disturbance occurrence to a large extent also affect disturbance intensity, and hence the magnitude of ϵ . However only the annual mean ϵ -distribution is presented, because it is felt that the seasonal variation in ϵ is too small, and the ϵ -database too sketchy, to warrant a seasonal analysis.

6.4 The Probability Distribution of Disturbance Intensity

Nastrom and Gage (1985) calculated the empirical frequency distributions of the spectral power of GASP wind and temperature data in the band centered at a wavelength of 400 km. Their results for meridional and zonal wind speeds, and for potential temperature, are shown in Fig. 6.4-1. Probability density functions are plotted in Fig. 6.4-1a in standard histogram format, with the common logarithm of spectral power used along the

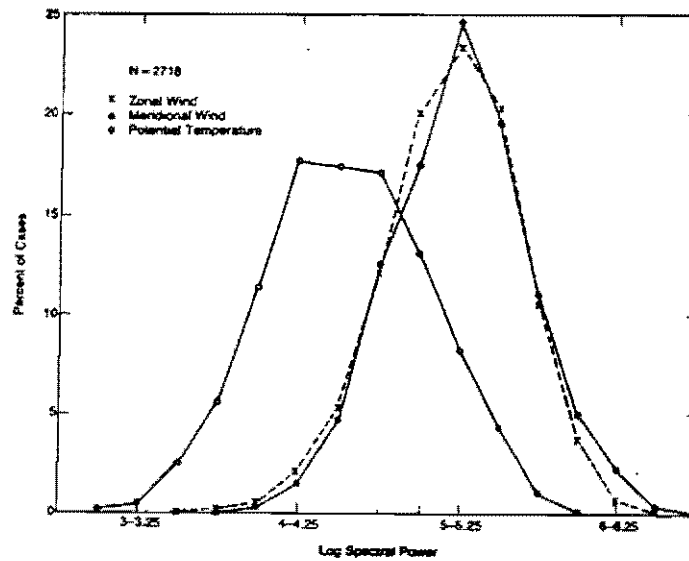


Annual mean eddy dissipation rate

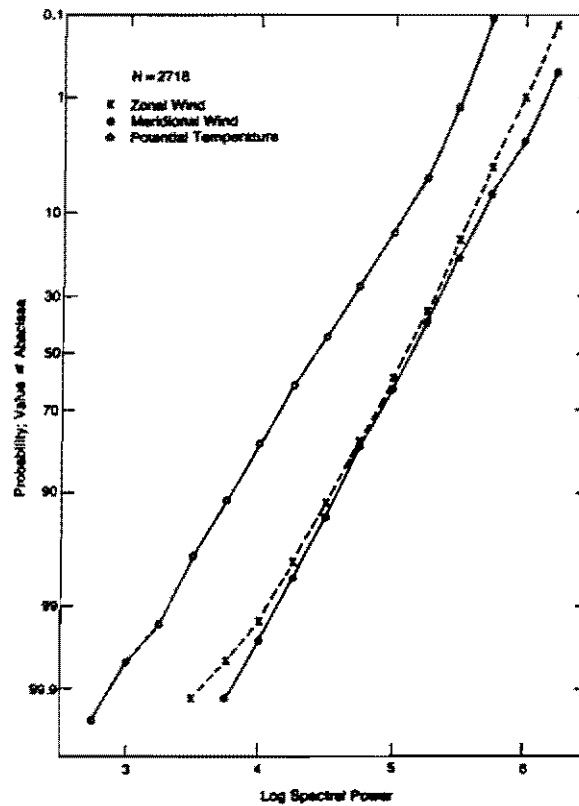


Anticipated HSCT route structure

Fig. 6.3-1. The upper panel shows the geographic distribution of the annual mean eddy dissipation rate over Northern Hemisphere oceans at HSCT cruise altitudes (multiply isopleth values by 10^{-5} for dissipation rates in units m^2sec^{-3}). The geographic distribution of the HSCT route structure is shown once more for comparison in the lower panel.



a.) Frequency distributions



b.) Cumulative probabilities

Fig. 6.4-1. a.) The frequency distributions of power densities of stratospheric component wind speeds and potential temperature in the band centered at a wavelength of 400 km, as calculated from the GASP data; and b.) the associated cumulative probability distributions (Nastrom and Gage, 1985, courtesy of the American Meteorological Society).

abscissa. The associated cumulative distributions are plotted on log normal probability coordinates in Fig. 6.4-1b.

Noteworthy in these plots is the apparently log-normal distribution of all three variables; i.e., the pdf and cumulative probability for the power density at a *specified wavenumber* k , S_k , can be expressed, respectively, as

$$p(u) = \frac{1}{s\sqrt{2\pi}} e^{-\frac{(u-\bar{u})^2}{2s^2}} \quad (28)$$

$$P(u) = \int_{-\infty}^u f(u) du \quad (29)$$

where $u = \log S_k$, with distribution mean, \bar{u} , and standard deviation, s , given by

$$\bar{u} = \frac{1}{N} \sum_{i=1}^N \log S_k$$

$$s^2 = \frac{1}{N-1} \sum_{i=1}^N (\log S_k - \bar{u})^2$$

The log normal distribution of the variables is especially evident in Fig. 6.4-1b, where the coordinates are designed so that the cumulative probability plots as a straight line. In this plot, the mean as defined above is at the 50 percent intercept and the standard deviation is proportional to the straight line slope. Nastrom and Gage (1985) calculated standard deviations for zonal and meridional wind and potential temperature of 0.41, 0.43, and 0.52, respectively.

The pdf for the total disturbance variance required for the conditional unstart probability calculation (cf. eq. (12)), may now be determined from the

pdf for spectral power at a specified wavenumber as follows. The variable u as used in eqs. (28) and (29) is a transformation of the variable S_k , with the inverse relation

$$S_k = 10^u \quad (30)$$

The relation between the pdf's of transformed and original variables is (Hahn and Shapiro, 1967)

$$p(u) = p(S_k) \left| \frac{dS_k}{du} \right| \quad (31)$$

where the absolute value of the derivative is the Jacobian of the transformation. Thus from eqs. (30) and (31)

$$p(S_k) = \frac{1}{\ln 10} \frac{1}{S_k \sqrt{2\pi}} e^{-\frac{(\log S_k - \bar{u})^2}{2s^2}} \quad (32)$$

Now consider that the 400 km wavelength used for the frequency distributions shown in Fig. 6.4-1 marks the break between the -3 and -5/3 power laws in the PSD plots shown in Fig. 5.3-1. It thus marks the "outer scale" for the -5/3 power law representation of disturbance PSD behavior; i.e., the -5/3 power law holds to a maximum disturbance scale size of $L_o = 400$ km, or to a minimum wavenumber $k = 1/L_o$ (cf. Section 5.3.2.2). In this context eq. (16) for the total disturbance variance may be written

$$\sigma^2 = \int_{k=1/L_o}^{\infty} S(k) dk = \frac{3}{2} A L_o^{2/3} \quad (33)$$

where the explicit integration is according to eq. (19) with $m = 5/3$. Also, the spectral power at $k = 1/L_o$ is

$$S_{k=1/L_o} = AL_o^{5/3} \quad (34)$$

Combining eqs. (33) and (34),

$$\sigma^2 = \left(\frac{3}{2} \frac{1}{L_o} \right) S_{k=1/L_o} \quad (35)$$

Thus σ is shown as a transformation of the variable S_k ; therefore, again according eq. (33),

$$p(\sigma_i) = \frac{2}{\ln 10} \frac{1}{s_i \sqrt{2\pi} \sigma_i} e^{-\frac{\left[2 \log \sigma_i + \log \left(\frac{2}{3} L_o \right) - \bar{u} \right]^2}{2 s_i^2}} \quad (36)$$

where the subscript "i" has been added to indicate eq. (36) is the pdf for each type of disturbance. Note that these pdf's are again log normally distributed.

Finally, substitution of equations (34) and (35) into eq. (36) yields an expression for the pdf of disturbance intensity in terms of ϵ :

$$p(\sigma_i) = \frac{1}{\ln 10} \frac{1}{s_i \sqrt{3\pi a_i} (L_o \epsilon)^{1/3}} e^{-\frac{\left[\frac{2}{3} \log \left(\frac{\epsilon}{\bar{\epsilon}} \right) \right]^2}{2 s_i^2}} \quad (37)$$

where ϵ is the mean ϵ from Fig. 6.3-1, and where a_i represents the numerical parts of the coefficients A_i given in Table 5.3-1. In this equation the standard deviation s_i is treated as a constant independent of ϵ , and of the magnitudes reported by Nastrom and Gage (1985). This in effect says that the straight line representation of the σ_i cumulative probability changes with changing ϵ only in the position of the 50 percent intercept; the slope remains constant. Equation (37) completes the presentation of the conditional inlet unstart probability model in terms of the single atmospheric parameter, the

eddy dissipation rate.

6.5 Summary

The global distribution of annual mean eddy dissipation rate, ϵ , is presented in Fig. 6.3-1. The data were computed from power law representations of disturbance velocity spectra generated from *in situ* disturbance data obtained with airborne sensors in the lower stratosphere. Data were extrapolated to the areas and altitudes of the HSCT route structure, in reference to established relationships between disturbance intensity and bulk atmospheric structure. These data quantify the free stream disturbance PSD's needed to calculate the affect of disturbances on inlet mass flow.

An equation was derived (eq. (37)) for the probability density function of disturbance intensity as a function of ϵ . This equation for disturbance intensity completes the model for inlet unstart probability calculations in terms of a single atmospheric parameter.

7.0 Applications

7.1 Inlet Unstart Probability

Given knowledge of inlet-specific unstart transfer functions, the data in Figs. 3.3-1 and Fig. 6.3-1 can be used to calculate the unstart probability. The steps in the calculation are as follows.

Step 1. Choose representative values for $P(E)$ (the prior disturbance occurrence probability) and ϵ (the eddy dissipation rate) for the HSCT operations area of interest.

Step 2. Use the selected ϵ to quantify free-stream disturbance input spectra according to eq.(19), and the data in Table 5.3-1.

Step 3. Use eq.(10) to calculate throat Mach number and shock position output PSD's.

Step 4. Calculate the ratio of the output to the input PSD's according to eq.(11).

Step 5. Numerically integrate eq.(12) using eqs. (16) and (37) for σ_i and $p(\sigma_i)$, to determine the conditional inlet unstart probability for specified thresholds in inlet Mach number and shock position.

Step 6. Multiply the prior disturbance encounter probability by the conditional unstart probability, for the joint probability of the encounter and the unstart.

This process will determine whether the inlet is sensitive to unstart because of Mach number or shock position transients; and it will further serve to identify the free-stream disturbance parameter which is critical to the unstart problem.

7.2 Time-to-failure

Once the critical parameter for unstart is identified as described in the previous section, then the number of times (per flight mile or hour) the unstart threshold for that parameter is exceeded -- i.e., the worst case unstart *rate* -- can be calculated from (Barry, 1973)

$$N(y) = P(E, y) \sqrt{\frac{\int_0^{k_{off}} k^2 S_{ii}(k) dk}{\int_0^{k_{off}} S_{ii}(k) dk}} \quad (38)$$

This is the hazard function for an exponentially distributed "time-to-failure" probability density function; and the cumulative probability of a single un-

start event, or inlet "failure," during any specified period, Λ (number of flight miles or hours), is given by (Hahn and Shapiro, 1967)

$$F[\Lambda; N(y)] = 1 - \exp[-\Lambda N(y)] \quad (39)$$

This parameter is used in system design analyses.

7.3 Disturbance Simulations

An alternative expression (to eq.(15)) for a disturbance PSD is in terms of the squares of sine and cosine coefficients for a finite, discrete Fourier series that describes the random disturbance record (Fairall, *et al*, 1991)

$$S_{ij}(k) = 0.5 (A_n^2 + B_n^2) / dk \quad (40)$$

where n is an integer. The Fourier series is used to represent the spatial function

$$D_i(l) = \sum_{n=1}^M [A_n \cos(2\pi knl) + B_n \sin(2\pi knl)] \quad (41)$$

where l is distance, say, along a flight track.

Because the PSD for any disturbance is known once ϵ is specified, a disturbance record with the proper statistical characteristics (rms amplitude, autocovariance function) can be simulated by choosing A_n and B_n randomly so that eqs.(20) and (40) are satisfied simultaneously. An example of this sort of simulation is shown in Fig. 7.3-1. This is a simulated sequence of longitudinal (i.e., headwind) gust speeds along a 100 km flight track that results in a $k^{-5/3}$ PSD with $\epsilon = 10^{-5}$. This procedure could be used for a time-domain simulation of the response of an inlet to the disturbed, free-stream environment.

The simulation technique just described is similar to that used by Justus, *et al* (1991) in the NASA/MSFC Global Reference Atmosphere Model

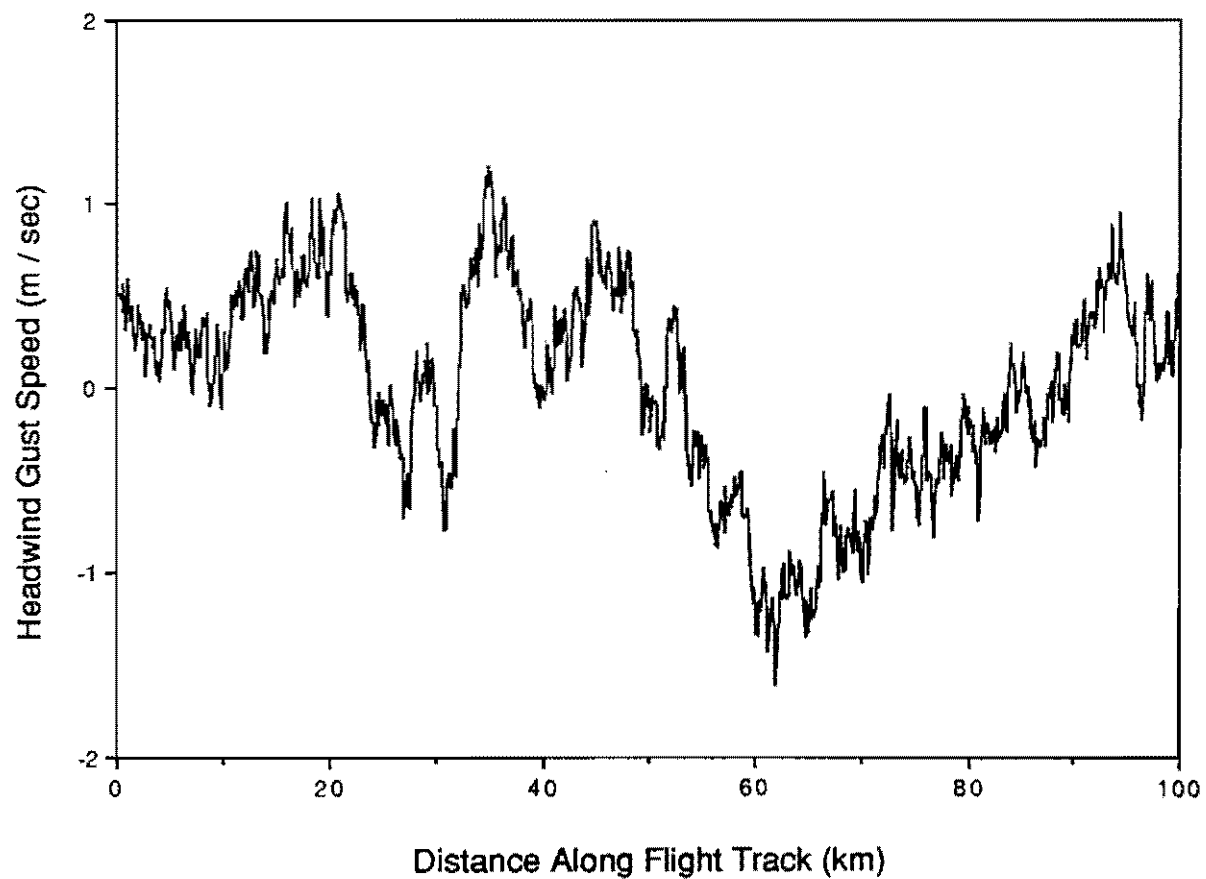


Fig. 7.3-1. Simulated headwind gust speed along a 100 km flight track, assuming a $k^{-5/3}$ power law PSD with $\epsilon = 10^{-5} \text{ m}^2\text{sec}^{-3}$.

(GRAM-90) to simulate psuedo-random perturbations in density, temperature, pressure or wind components along arbitrary atmospheric paths. The main difference is that here the atmospheric disturbance spectra is represented by a $-5/3$ power law, whereas GRAM-90 uses a -2.0 law for the representation.

7.4 Summary

Equations are identified, and procedures described, for calculating inlet unstart probability, and the probability of a single unstart within an arbitrary time or space interval. A technique is also presented for simulating the spatial distribution of random disturbances along an HSCT flight track. The latter technique will be especially useful for CFD simulations of inlet response to a disturbed, free stream environment.

8.0 Summary and Conclusions

Free-stream disturbance databases are lacking both in content and quantity in the areas and at the altitudes of supersonic HSCT flight. Therefore, extensive extrapolation of the limited data available was used to develop the statistical treatment of disturbances needed for an analysis of inlet unstart probability.

The unstart probability was considered a joint probability as the product of a.) the *a priori* or prior probability of a disturbance encounter, by b.) the conditional probability given the encounter, that the disturbance is of sufficient magnitude to cause unstart. These prior and conditional probabilities were analyzed separately. The climate of the prior probability of a disturbance encounter as simply the local frequency-of-occurrence of the disturbed environment at HSCT supersonic cruise altitudes, is as presented in Figs. 3.3-1.

Disturbance power spectral densities (PSD's), or variance spectra, relate directly to inlet mass flow transients, and so determine the conditional probability of inlet unstart due to throat choking or to the shock

moving forward to the throat. Accordingly, free-stream disturbances as climatic elements were considered as continuous, random processes, describable in terms of power spectral densities of a universal shape, but with rms amplitudes as functions of geographic location and season. These spectral amplitudes were expressed in terms of a single atmospheric parameter, the eddy dissipation rate, ϵ .

An equation was also derived (eq. (37)) giving the probability density function of disturbance intensity as a function of ϵ . This equation, along with the PSD representations, completes the model for inlet unstart probability in terms of a single atmospheric parameter. An ϵ -climate developed for ocean areas at HSCT supersonic cruise altitudes is shown in Fig. 6.3-1. As inlet-specific transfer functions that relate free-stream disturbances to inlet mass flow transients become known, the ϵ -climate in Fig. 6.3-1 effectively determines the global distribution of conditional inlet unstart probability.

Steps for calculating the global distribution of inlet unstart probability were outlined. Additionally, procedures were described for a.) calculating the probability of a single unstart during an arbitrary interval in time or space; and b.) for simulating the spatial distribution of random disturbances along an arbitrary HSCT flight track. This latter result will be particularly useful in performing time domain simulations of the response of mixed compression inlets to a disturbed environment.

9.0 References

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APPENDIX

THEORY

Preliminary Climatology of the Spectrum of Vertical Velocity Observed by

Clear-Air Doppler Radar

Ecklund, W. L. ; Gage, K. S. ; Nastrom, G. D. ; Balsley, B. B.

Colorado Univ. at Boulder. Dept. of Astrophysical Science.

Corp. Source Codes: 068646032; 415862

Sponsor: Air Force Office of Scientific Research, Bolling AFB, DC.

Report No.: AFOSR-TR-87-0262

Jul 86 9p

Languages: English Document Type: Journal article

Journal Announcement: GRAI8712

Pub. in Jnl. of Climate and Applied Meteorology, v25 n7 p885-892 Jul 86.

NTIS Prices: PC A02/MF A01

Country of Publication: United States

Contract No.: F49620-82-C-0029; 2310; A1

Multiheight time series of atmospheric vertical velocities in the troposphere and lower stratosphere observed by clear-air Doppler radar are presented at various locations around the world. Frequency spectra of vertical velocities determined from these data sets are compared with the objective of developing a preliminary climatology. We emphasize the nearly universal shape and magnitude of spectra observed during low-wind conditions. These spectra are quite flat for frequencies between the buoyancy and inertial frequencies, and they closely resemble the internal wave spectra observed in the ocean. Spectra observed under strong wind conditions, on the other hand, are greatly enhanced in magnitude, approaching the F to the minus $5/3$ rd power spectral slope observed for the spectrum of horizontal motions. Finally, spectra determined from both quiet and active periods at Poker Flat, Alaska, possess spectral slopes and amplitudes intermediate to those spectra determined solely from quiet or active periods at other locations. (Reprints).

99 (Item 3 from file: 6)

752015 NTIS Accession Number: PB80-130339

Detection of Clear-Air Turbulence by Water Vapour Emission Variations -

Transmittances and Weighting Functions

(Final rept.)

Platt, C. M. R.

Commonwealth Scientific and Industrial Research Organization, Aspendale (Australia). Div. of Atmospheric Physics.

Corp. Source Codes: 007209002

Sponsor: National Oceanic and Atmospheric Administration, Boulder, CO. Atmospheric Physics and Chemistry Lab.

Report No.: NOAA-79110204

Aug 79 32p

Languages: English

Journal Announcement: GRAI8008

NTIS Prices: PC A03/MF A01

Country of Publication: Australia

Contract No.: NOAA-04-78-1301-20

A simple model of a water vapor disturbance (assumed to be caused by clear air turbulence) in the stratosphere or upper troposphere is used to investigate the changes in emission along a slant path which an aircraft detector would view when encountering such a disturbance ahead of the aircraft. Transmittances for the 260/cm to 500/cm spectral region are calculated along slant paths assuming detector viewing angles above the horizon of from 0.5 degrees to 10 degrees. Weighting functions in terms of the transmittance rate of change with water path and the radiance rate of change with time are investigated for water vapor increases in a disturbance of 10 ppm. The predicted radiance changes are compared with known radiometer sensitivities and with actual changes observed by Kuhn et al.

100 (Item 4 from file: 6)

562808 NTIS Accession Number: AD-A036 307/7

Theoretical Explanation of Spectral Slopes in Stratospheric Turbulence

Data and Implications for Vertical Transport

(Environmental research papers)

Dewan, Edmond M.

Air Force Geophysics Lab Hanscom AFB Mass

Corp. Source Codes: 409578

Report No.: AFGL-TR-76-0247; AFGL-ERP-581

18 Oct 76 49p

Journal Announcement: GRAI7710

NTIS Prices: PC A03/MF A01

Contract No.: 6687; 05

This paper is motivated by the requirement to improve understanding of vertical motion of pollutants in the stratosphere. One method to estimate vertical transport due to the effects of turbulence is by means of the effective diffusivity coefficient. To calculate this parameter, it is often necessary to know the value of epsilon, the rate of turbulent dissipation. This parameter, epsilon, is also important to know in the context of the global numerical stratospheric simulation models now being created for environmental assessment purposes.

103 (Item 7 from file: 6)

252860 NTIS Accession Number: N71-36398

Relation Between Stratosphere Turbulence Causing Aircraft Buffeting and

the Vertical Distribution of Meteorological Parameters . Svyaz

Turbulentnosti V Stratosfere, Vyzhivayushchey Boltanku Samoletov, S

Vertikalnym Raspredeleniyem Meteorologicheskikh Parametrov

Buldovskiy, G. S.

Translation Consultants, Ltd., Arlington, Va.

Report No.: NASA-TT-F-13981

Oct 71 18p

Document Type: Translation

Journal Announcement: GRAI7204; STAR0923

Transl. Into English From Gidrometeoizdat (ussr), No. 70, 1970 P
79-92

NTIS Prices: PC A02/MF A01
Contract No.: NASW-2038
No abstract available.

107 (Item 11 from file: 6)
114373 NTIS Accession Number: AD-676 081

Undulance and Turbulence in Stably Stratified Media

Pao, Yih-Ho
Boeing Scientific Research Labs Seattle Wash Flight Sciences Lab
Corp. Source Codes: 400753
Report No.: D1-82-0742
Aug 68 30p
Journal Announcement: USGRDR6823
NTIS Prices: PC A03 MF A01

The origin and the structure of undulance and turbulence in stably stratified media are investigated through theoretical reasoning and laboratory experiments. The mechanisms for generating turbulence in stably stratified media are linked with the mechanisms for generating vorticity - shear and stratification. The dual role of stable stratification -- the capability for generating and attenuating turbulence -- is pointed out. The turbulence induced by stable stratification is evidenced in two experimental results: (1) turbulent rotors in the lee of a barrier in a stably stratified fluid, and (2) the breaking of traveling internal waves on a sloping surface. The ability of stable stratification to generate turbulence is also indicated from an exact solution for an inviscid stably stratified flow past a barrier. The structure of undulance and turbulence in stably stratified media is investigated in a stratified salt water towing tank, with schlieren photographs, quartz-coated hot-film probes, and single electrode conductivity probes. The schlieren photographs show clearly the collapse of a turbulent wake and the attenuation of turbulence by stable stratification. Auto-correlations and -spectra for the streamwise turbulent velocity field and for the turbulent concentration field are obtained. From the measured correlations and spectra, the combined wave-turbulence behavior is clearly shown, and the turbulence is strongly anisotropic. (Author)

109 (Item 1 from file: 2)
02384865 INSPEC Abstract Number: A85023903

Title: Simultaneous measurements of temperature and velocity fluctuations

within *clear* *air* *turbulence* layers: analysis of the estimate of dissipation rate by remote sensing techniques

Author(s): Barat, J.; Bertin, F.

Author Affiliation: Paris VI Univ., France

Journal: Journal of the Atmospheric Sciences vol.41, no.9 p.1613-19

Publication Date: 1 May 1984 Country of Publication: USA

CODEN: JAHSAK ISSN: 0022-4928

Language: English Document Type: Journal Paper (JP)

Treatment: Experimental (X)

Abstract: Estimates of dissipation rate from remote-sensing techniques measuring the structure parameter C_{n^2}/ϵ of density turbulent fluctuations assume a relationship between C_{n^2}/ϵ and the dissipation rate ϵ . In order to obtain a precise test of this relation, in situ observations are of major importance. The authors present

in this paper the first simultaneous in situ measurements of these parameters. The analysis of data shows that the models of turbulence used in the radar literature are not always fully justified and that the estimate of dissipation rate may be underestimated. (23 Refs)

111 (Item 3 from file: 2)

01300494 INSPEC Abstract Number: A79016585

Title: Vertical turbulent diffusion in a stably stratified fluid

Author(s): Weinstock, J.

Author Affiliation: Aeronomy Lab., NOAA, Boulder, CO, USA

Journal: Journal of the Atmospheric Sciences vol.35, no.6 p.1022-7

Publication Date: June 1978 Country of Publication: USA

CODEN: JAHSAK ISSN: 0022-4928

Language: English Document Type: Journal Paper (JP)

Treatment: Theoretical (T)

Abstract: The vertical turbulent diffusion coefficient is derived analytically. This derivation does not require that the flux Richardson number be known or specified. The resulting expression for the diffusion coefficient is compared with the stratospheric results of Lilly et al. (1974) and its applicability to atmospheric diffusion and clear air turbulence is discussed. (22 Refs)

112 (Item 4 from file: 2)

01115547 INSPEC Abstract Number: A77086968

Title: The effect of *clear*-air* turbulence* on a model of the general

circulation of the atmosphere

Author(s): Heck, W.J.; Panofsky, H.A.; Bender, M.A.

Author Affiliation: Dept. of Meteorology, Pennsylvania State Univ., University Park, PA, USA

Journal: Contributions to Atmospheric Physics vol.50, no.1-2 p. 89-97

Publication Date: 1977 Country of Publication: West Germany

CODEN: BPYAAY ISSN: 0005-8173

Conference Title: International Conference on Simulation of Large-Scale Atmospheric Processes

Conference Date: 30 Aug.-4 Sept. 1976 Conference Location: Hamburg, West Germany

Language: English Document Type: Conference Paper (PA); Journal Paper (JP)

Treatment: Theoretical (T); Experimental (X)

Abstract: Mixing coefficients due to clear-air turbulence are estimated from turbulence observations from aircraft, and from large-scale dissipation estimates from the large-scale energy budgets. Maximum coefficients occur near middle-latitude jet streams, and eddy viscosity there is of order of $10 \text{ m}^2/\text{s}$; eddy conductivity is estimated to be about ten times smaller. These coefficients are introduced into the 12-layer general circulation model of the National Center of Atmospheric Research. They produce an apparently significant, though small, reduction in maximum speed of the jet and a reduction in eddy energy. Further, the stratospheric polar-night jet is produced at about the correct location with about the correct intensity. (14 Refs)

113 (Item 5 from file: 2)

01073909 INSPEC Abstract Number: A77056676

Title: Energy dissipation within intermittent *clear* *air*
turbulence
patterns

Author(s): Cadet, D.

Author Affiliation: Lab. de Meteorologie Dynamique, Ecole Polytechnique,
Palaiseau, France

Journal: Journal of the Atmospheric Sciences vol.34, no.1 p.137-42

Publication Date: Jan. 1977 Country of Publication: USA

CODEN: JAHSAK ISSN: 0022-4928

Language: English Document Type: Journal Paper (JP)

Treatment: Theoretical (T); Experimental (X)

Abstract: Mean dissipation rates of kinetic energy in the lower stratosphere are estimated from data obtained with an instrumented, superpressure, constant-level balloon launched to measure the vertical wind shear at 200 mb. The flight record shows that while the balloon was located above a mountainous region localized patches of turbulence were encountered. (14 Refs)

115 (Item 7 from file: 2)

00316079 INSPEC Abstract Number: A71074317

Title: An analysis of heat-, momentum-transport, and spectra for
clear

air *turbulence* in mid-*stratosphere*

Author(s): Kao, S.-K.; Gebhard, J.B.

Author Affiliation: Univ. Utah, Salt Lake City, UT, USA

Journal: Pure and Applied Geophysics vol.87, no.5 p.180-5

Publication Date: 1971 Country of Publication: Switzerland

CODEN: PAGYAV ISSN: 0033-4553

Language: English Document Type: Journal Paper (JP)

Treatment: Theoretical (T)

Abstract: An analysis of the clear air turbulence in the mid-stratosphere indicates that the turbulence is characterized by an anisotropic field of turbulence with an intense lateral component of the turbulence, associated with strong thermally stable stratification. The Richardson number in the region of turbulence is generally smaller than $1/4$, the Taylor's criterion for a stratified shear flow. The cospectra for the momentum transport by the streamwise, lateral, and vertical components of the velocity show similarity in their distribution, decreasing with increasing wavenumber. The cospectra for the heat transport by the streamwise, lateral, and vertical components of the velocity show similarity in their distribution, decreasing with increasing wavenumber. The cospectra for the heat transport by the streamwise, lateral and vertical components of the velocity show similarity in the high and medium wavenumber ranges, but not in the low wavenumber range of the spectra. The power spectra of the temperature and wind speed are very similar, and are approximately proportional to the $^{-5/3}$ power of the wavenumber. The power spectra of the streamwise and lateral components of the velocity are approximately proportional to the $^{-2}$ power of the wavenumber, whereas the spectrum of the vertical component of the velocity is approximately proportional to the $^{-1}$ power of the wavenumber. (12 Refs)

123 (Item 1 from file: 434)

11102474 Genuine Article#: GG358 Number of References: 40

**Title: A STOCHASTIC-MODEL OF GRAVITY-WAVE INDUCED *CLEAR*-*AIR*
*TURBULENCE***

Author(s): FAIRALL CW; WHITE AB; THOMSON DW

Corporate Source: NOAA,ERL,ATMOSPHER STUDIES PROGRAM AREA,325

**BROADWAY/BOULDER//CO/80303; PENN STATE UNIV,DEPT METEOROL/UNIVERSITY
PK//PA/16802**

Journal: JOURNAL OF THE ATMOSPHERIC SCIENCES, 1991, V48, N15, P1771-1790

Language: ENGLISH Document Type: ARTICLE

Abstract: We examine the consequences of using a vertical wavenumber spectral model to describe variations of vertical profiles of atmospheric variables (horizontal and vertical wind, temperature, and other scalars) about a mean profile. At high wavenumbers the model exhibits a wavenumber to the -3 dependence, which is characteristic of a continuum of internal gravity waves whose amplitudes are controlled by a breaking process.

By employing a random phase between wavenumber amplitude components, a reverse fourier transform of the spectrum yields simulated profiles of velocity and thermal variability as well as shear and Brunt-Vaisala frequency variability. Individual components of the vertical shear of the horizontal wind and the Brunt-Vaisala frequency exhibit Gaussian distributions; the square of the magnitude of the shear exhibits a Rice-Nakagami distribution. Assuming regions with $Ri < 0.25$ are turbulent, we can examine a number of aspects of the occurrence of clear-air turbulent breakdown in the stratified free atmosphere. For a typical tropospheric condition, the average turbulent layer thickness turns out to be about 35 m and about 20% of the troposphere appears to be actively turbulent. The majority of the turbulent layers appear to be due to autoconvective overturning instead of Kelvin-Helmholtz dynamic instability. Computations of profiles of the refractive index structure function parameter, $C(n)^2$, and the rate of dissipation of turbulent kinetic energy, epsilon, are found to be quite sensitive to the assumptions of the relationship of turbulent length scale to layer thickness, the growth of turbulent layers after breakdown, and the threshold sensitivity and sampling strategy of measurement systems (e.g., clear-air radar).

1 (Item 1 from file: 108)

1783800 A91-42460

Enhanced autoregressive moving average spectral estimation applied to the

measurement of Doppler spectral width

PALMER, ROBERT D. (Clemson University, SC); CRUZ, J. R. (Oklahoma, University, Norman); ZRNIC, DUSAN S. (NOAA, National Severe Storms Laboratory, Norman, OK)

IEEE Transactions on Geoscience and Remote Sensing (ISSN 0196-2892), vol. 29, May 1991, p. 358-368.

Publication Date: May 1991 37 Refs.

Contract No.: NSF RII-86-10676

Language: English

Country of Origin: United States Country of Publication: United States

Document Type: JOURNAL ARTICLE

Documents available from AIAA Technical Library

Journal Announcement: IAA9117

The measurement of clear-air turbulence with a Doppler radar is investigated. An autoregressive moving average (ARMA) model is proposed to improve the Doppler spectral width estimates. An iterative algorithm that has its origin in system identification is used for the estimation of the ARMA parameters. By taking advantage of a priori knowledge of the correlation matrix, which arises in the derivation of the governing equations of the ARMA parameters, the ARMA spectral estimate can be improved. This improvement is shown in terms of bias and variance of the spectral width estimate. Furthermore, examples of the usefulness of this algorithm on actual experimental Doppler radar data are presented. (I.E.)

Source of Abstract/Subfile: AIAA/TIS

4 (Item 4 from file: 108)

1516784 N87-22349

CAT-generating mechanisms

WURTELE, MORTON G.

California Univ., Los Angeles.

In NASA. Langley Research Center Atmospheric Turbulence Relative to Aviation, Missile and Space Programs p 111-126 (SEE N87-22341 15-47)

Publication Date: Apr. 1987

Language: English

Country of Origin: United States Country of Publication: United States

Document Type: CONFERENCE PAPER

Documents available from AIAA Technical Library

Other Availability: NTIS HC A12/MF en1

Journal Announcement: STAR8715

The development of instability configurations; the transition from unstable growth of these configurations into turbulence; a description of the nature of that turbulence; the question of decay of turbulence; and the existence of what is called fossil turbulence are discussed. (Author)

Source of Abstract/Subfile: NASA STIF

5 (Item 5 from file: 108)

1446752 A86-30692

Wave-turbulence interaction in the stratosphere - A case study

COT, C.; BARAT, J. (CNRS, Service d'Aeronomie, Verrieres-le-Buisson, France)

Journal of Geophysical Research (ISSN 0148-0227), vol. 91, Feb. 20, 1986, p. 2749-2756.

Publication Date: Feb. 1986 24 Refs.

Language: English

Country of Origin: France Country of Publication: United States

Document Type: JOURNAL ARTICLE

Documents available from AIAA Technical Library

Journal Announcement: IAA8613

The wave motion and turbulence field in the stratosphere are studied simultaneously using high resolution measurements of the vertical wind shear obtained from differential sounding performed between 19-24 km on July 1, 1976 in Gap-Tallard, France. The wind shear profile measured over a 150 m interval is analyzed and the wave characteristics are evaluated using Kundu's (1976) method. The data reveal that a wave of long period and of short vertical wavelength may propagate upward with a slight variation in amplitude. The turbulence field is examined and the mean dissipation rate

along the 5-km sounding is calculated. The energy budget wave interaction is described and it is observed that a small portion of the wave energy is dissipated within irreversible processes. The data obtained in this experiment is applicable to the study of the spatiotemporal structure of the clear air turbulence layer. (I.F.)

Source of Abstract/Subfile: AIAA/TIS

7 (Item 7 from file: 108)

1426859 A86-18095

On the spectrum of atmospheric velocity fluctuations seen by MST/ST radar

and their interpretation

GAGE, K. S. (NOAA, Aeronomy Laboratory, Boulder, CO); NASTROM, G. D. (Control Data Corp., Minneapolis, MN)

Radio Science (ISSN 0048-6604), vol. 20, Nov.-Dec. 1985, p. 1339-1347. NSF-USAF-supported research.

Publication Date: Dec. 1985 34 Refs.

Language: English

Country of Origin: United States Country of Publication: United States

Document Type: JOURNAL ARTICLE

Documents available from AIAA Technical Library

Journal Announcement: IAA8606

Observations of the spectrum of atmospheric motions over the range of periods from a few minutes to many hours that have been made with ST/MST radars in the past five years are considered. The spectra of both horizontal and vertical velocities are considered, and their interpretation is examined in terms of buoyancy wave theory and turbulence theory. It is found that radar and aircraft horizontal wind spectra are in reasonable accord with expectations from quasi-two-dimensional turbulence theory. The vertical velocity spectra are believed to be due to waves. Comparison of the energy levels and shapes of the horizontal and vertical velocity spectra are not consistent with existing models of internal wave spectra. However, it is possible that these inconsistencies arise from Doppler-shifting effects that are not taken into account in existing internal wave models. Nevertheless, all the observations examined support the hypothesis that quasi-two-dimensional turbulence coexists with a nearly universal spectrum of buoyancy waves. (Author)

Source of Abstract/Subfile: AIAA/TIS

12 (Item 12 from file: 108)

1351064 A76-39522

The role of turbulent heat flux in the generation of potential vorticity in the vicinity of upper-level jet stream systems

SHAPIRO, M. A. (National Center for Atmospheric Research, Boulder, Colo.)

Monthly Weather Review, vol. 104, July 1976, p. 892-906.

Publication Date: Jul. 1976 28 Refs.

Language: English

Country of Origin: United States Country of Publication: United States

Document Type: JOURNAL ARTICLE

Documents available from AIAA Technical Library

Journal Announcement: IAA7619

Results from three case-study investigations of upper-level jet-stream systems document the existence of stratospheric mesoscale cyclonic wind

shear in the layer of maximum wind. Anomalously high values of potential vorticity are shown to coincide with the mesoscale cyclonic shear-zone. The high values of potential vorticity within an upper-level frontal zone were shown to result from shearing vorticity in the mesoscale high-potential-vorticity region of the stratosphere, which is transported downward into the tropospheric frontal zone and becomes transformed into curvature vorticity with little change in thermal stability. The vertical gradient of diabatic temperature change resulting from vertical shear-induced turbulent heat flux in layers of clear air turbulence is proposed as the generation mechanism responsible for large values of potential vorticity on the mesoscale. It is proposed that turbulent-scale mixing processes are of first-order importance in the evolution of jet-stream frontal-zone systems. ((Author))

13 (Item 13 from file: 108)

1317011 A84-37387

On the contamination of stratospheric turbulence measurements by wind shear

BARAT, J. (CNRS, Service d'Aeronomie, Verrieres-le-Buisson, Essonne, France); BERTIN, F. (CNRS and CNET, Centre de Recherches en Physique de l'Environnement Terrestre et Planetaire, Issy-les-Moulineaux, Hauts-de-Seine, France)

Journal of the Atmospheric Sciences (ISSN 0022-4928), vol. 41, March 1, 1984, p. 819-827.

Publication Date: Mar. 1984 21 Refs.

Language: English

Country of Origin: France Country of Publication: United States

Document Type: JOURNAL ARTICLE

Documents available from AIAA Technical Library

Journal Announcement: IAA8417

Analysis of the velocity field measured by balloon-borne anemometers through a clear air turbulent patch is presented. It is shown that, except in the case where the balloon altitude is constant, the vertical wind shear related to nonturbulent motions may create a contamination above the outer scale of the turbulent field. The result is typical of all turbulence measurements obtained along non-constant altitude trajectories: it may explain some intriguing characteristics of the gust velocity spectra measured by instrumented aircraft. (Author)

Source of Abstract/Subfile: AIAA/TIS

14 (Item 14 from file: 108)

1250282 A83-36142

Poker Flat MST radar observations of shear-induced turbulence (Mesosphere-Stratosphere-Troposphere)

SMITH, S. A.; ROMICK, G. J.; JAYAWEERA, K. (Alaska, University, Fairbanks, AK)

Journal of Geophysical Research (ISSN 0148-0227), vol. 88, June 20, 1983, p. 5265-5271.

Publication Date: Jun. 1983 23 Refs.

Contract No.: AF-AFOSR-80-0286

Language: English

Country of Origin: United States Country of Publication: United States

Document Type: JOURNAL ARTICLE

Documents available from AIAA Technical Library

Journal Announcement: IAA8316

Measurements of wind speed and of the radio refractivity turbulence structure constant made with the Poker Flat (Alaska) mesosphere-stratosphere-troposphere radar are used in studying the development of clear air turbulence (CAT) near the tropopause. Arguments and observations suggesting that the radio refractivity turbulence structure constant is proportional to the intensity of turbulence are presented. The relationship between wind shear and turbulence is investigated by using time-laged cross correlations between vertical wind shear and log structure-constant time series. From an analysis of data gathered with spatial resolutions of 2200 m and 750 m, it is found that the correlation improves as the time and spatial resolutions of the measurements improve. The implications for forecasting CAT are considered on the basis of the correlation results and a comparison of radar data with National Weather Service CAT forecasts. (C.R.)

Source of Abstract/Subfile: AIAA/TIS

15 (Item 15 from file: 108)

1230083 A83-15938

Some characteristics of clear-air turbulence in the middle stratosphere

BARAT, J. (CNRS, Service d'Aeronomie, Verrieres le Buisson, Essonne, France)

Journal of the Atmospheric Sciences, vol. 39, Nov. 1982, p. 2553-2564.

Publication Date: Nov. 1982 25 Refs.

Language: English

Country of Origin: France Country of Publication: United States

Document Type: JOURNAL ARTICLE

Documents available from AIAA Technical Library

Journal Announcement: IAA8304

Analysis of clear-air turbulence measurements obtained from highly sensitive balloon-borne instrumentation is presented. Emphasis is placed on the structure of the turbulent velocity field in the inertial range. Regions of weak turbulence are found to be associated with low Richardson numbers and negative temperature gradients. Measurements of the turbulent energy intensity are presented. The extension of the inertial range is found to be consistent with theoretical values in the case of stably stratified flow. The turbulence intensity varies significantly over a two-hour time interval. An important result is the observational evidence for a $2/3$ law behavior in the structure function at scales where the turbulent velocity field cannot be isotropic: this behavior cannot be explained by a two-dimensional turbulence field. ((Author))

17 (Item 17 from file: 108)

1223702 N83-36608

Investigation of shear-induced turbulence by MST (Mesosphere-Stratosphere

-Troposphere radar)

Final Report, 1 Oct. 1980 - 30 Sep. 1982

ROMICK, G. J.; JAYAWEEA, K.; SMITH, S. A.

Alaska Univ., Fairbanks. Geophysical Inst.

Publication Date: Sep. 1982 32P.

Report No.: AD-A129203; AFOSR-83-0437TR

Contract No.: AF-AFOSR-0286-80; AF PROJ. 2310

Language: English

Country of Origin: United States Country of Publication: United States

Document Type: REPORT

Documents available from AIAA Technical Library

Other Availability: NTIS HC A03/MF A01

Journal Announcement: STAR8324

Wind speed and C sub N squared measurements made with the Poker Flat, Alaska MST radar are used to study the development of clear air turbulence (CAT) near the tropopause. Arguments and observations that indicate C sub N squared is proportional to the intensity of turbulence are presented. The relationship between wind shear and turbulence is examined using time-lagged cross correlations of measured shears and C sub N squared time series. From analysis of data taken with spatial resolutions of 2200 m and 750 m, it is found that the correlation improves as the time and spatial resolutions of the measurements improve. The implications for forecasting CAT are discussed, based on the correlation results and a comparison of radar data with National Weather Service CAT forecasts. (Author (GRA))

Source of Abstract/Subfile: DTIC

19 (Item 19 from file: 108)

1135028 A82-10278

Spectral parameter estimation of CAT radar echoes in the presence of fading clutter

SATO, T.; WOODMAN, R. F. (Arecibo Observatory, Arecibo, PR)

Arecibo Ionospheric Observatory, Puerto Rico.

In: Conference on Radar Meteorology, 19th, Miami Beach, FL, April 15-18, 1980, Preprints. (A82-10201 01-47) Boston, MA, American Meteorological Society, 1980, p. 568-574.

Publication Date: 1980 7 Refs.

Contract No.: NASA ORDER W-14569

Language: English

Country of Origin: Puerto Rico Country of Publication: United States

Document Type: CONFERENCE PAPER

Journal Announcement: IAA8201

The analysis technique and a part of the results obtained from CAT radar echoes from higher troposphere and lower stratosphere are presented. First, the effect of processing distortion caused by the periodogram method using FFT algorithm on the slowly fading ground clutter echo is discussed. It is shown that an extremely narrow clutter spectrum can spill over the entire frequency range if the data are truncated at a tie sorter than their correlation time affecting largely the estimation of the CAT spectrum contribution, especially when the latter is a few tens of dB weaker than the former. A nonlinear least squares fitting procedure is used to parameterize the observed power spectrum in terms of CAT echo power, Doppler shift, spectral width, and the parameters which specify the shape of the clutter component. (C.R.)

Source of Abstract/Subfile: AIAA/TIS

22 (Item 22 from file: 108)

1104256 A81-43422

Detection of clear air turbulence by water vapor emission anomalies
Weighting functions and sensitivities

PLATT, C. M. R. (Commonwealth Scientific and Industrial Research Organization, Div. of Atmospheric Physics, Mordialloc, Victoria, Australia)
Applied Optics, vol. 20, July 15, 1981, p. 2510-2516.

Publication Date: Jul. 1981 7 Refs.

Contract No.: NOAA-04-7-81301-20

Language: English

Country of Origin: Australia Country of Publication: United States

Document Type: JOURNAL ARTICLE

Documents available from AIAA Technical Library

Journal Announcement: IAA8120

In view of the fact that clear air turbulence (CAT) ahead of an aircraft can be sensed by a forward-looking IR radiometer tilted at a small elevation and detecting in the water vapor rotational emission band, radiance changes due to a model water vapor anomaly are calculated. The corresponding weighting function and its dependence on wavelength, altitude and viewing angle are investigated. The radiation transfer equation indicates that a weighting function that gives the change in transmittance with total water path is the most useful for the calculation of the water vapor emission changes due to CAT. It is shown to be possible to describe the water vapor emission in terms of an isothermal slant path to a good approximation. (O.C.)

Source of Abstract/Subfile: AIAA/TIS

25 (Item 25 from file: 108)
1060522 N80-23952

Detection of clear-air turbulence by water vapour emission variations:
Transmittances and weighting functions

Final Report

Commonwealth Scientific and Industrial Research Organization, Aspendale (Australia). Div. of Atmospheric Physics.

Publication Date: Aug. 1979 32P.

Report No.: PB80-130339; NOAA-79110204

Contract No.: NOAA-04-78-1301-20

Language: English

Country of Origin: Austria Country of Publication: United States

Document Type: REPORT

Documents available from AIAA Technical Library

Other Availability: NTIS HC A03/MF A01

Journal Announcement: STAR8014

A model of a water vapor disturbance (assumed to be caused by clear air turbulence) in the stratosphere or upper troposphere was used to investigate the changes in emission along a slant path which an aircraft detector would view when encountering such a disturbance ahead of the aircraft. Transmittances for the 260/cm to 500/cm spectral region were calculated along slant paths assuming detector viewing angles above the horizon of from 0.5 degrees to 10 degrees. Weighting functions in terms of the transmittance rate of change with water path and the radiance rate of change with time were investigated for water vapor increases in a disturbance of 10 ppm. The predicted radiance changes were compared with known radiometer sensitivities and with actual observed changes. (GRA)

26 (Item 26 from file: 108)
1031872 A80-39071

Turbulent mixing within tropopause folds as a mechanism for the exchange

of chemical constituents between the stratosphere and troposphere

SHAPIRO, M. A. (National Center for Atmospheric Research, Boulder, Colo.)

Journal of the Atmospheric Sciences, vol. 37, May 1980, p. 994-1004.

Publication Date: May 1980 20 Refs.

Language: English

Country of Origin: United States Country of Publication: United States

Document Type: JOURNAL ARTICLE

Documents available from AIAA Technical Library

Journal Announcement: IAA8016

Evidence is presented which illustrates the role of jet stream-frontal zone clear air turbulence as a mechanism for the exchange of air and chemical trace constituents between the stratosphere and the troposphere. Three-dimensional air motion sensing instrumentation and fast-response ozone and condensation nuclei analyzers on board research aircraft permit the quantitative evaluation of the turbulent flux of chemical constituents across the tropopause. The observations reveal that tropopause folds are mixing regions whose chemical characteristics lie somewhere in between those of the troposphere and the stratosphere. The temporal changes of ozone and condensation nuclei brought about through the vertical flux divergence of these quantities suggest that turbulent mixing processes are of first-order importance as a mechanism for stratospheric-tropospheric exchange in the vicinity of jet stream-frontal zone-associated tropopause folds. ((Author))

28 (Item 28 from file: 108)
0946320 A79-21937

Coherent radar systems for probing the troposphere, stratosphere, and

mesosphere (clear air meteorology)

BALSLEY, B. B.; GREEN, J. L. (NOAA, Aeronomy Laboratory, Boulder, Colo.)

In: Symposium on Meteorological Observations and Instrumentation, 4th, Denver, Colo., April 10-14, 1978, Preprints. (A79-21901 07-35) Boston, Mass., American Meteorological Society, 1978, p. 227-230.

Publication Date: 1978 16 Refs.

Language: English

Country of Origin: United States Country of Publication: United States

Document Type: CONFERENCE PAPER

Journal Announcement: IAA7907

Some clear-air pulse-Doppler systems, presently in use, are briefly discussed. It is shown that there are many radar parameters that may be varied in the design of a new system to meet the specific requirements for diverse meteorological applications. The technique under consideration has proved to be an effective versatile and economical research method for continuously monitoring the atmosphere with a high time resolution. With some further development and testing, the technique may find applications to diverse operational meteorological observation programs. (V.P.)

Source of Abstract/Subfile: AIAA/TIS

29 (Item 29 from file: 108)
0918196 N78-17634

Stratospheric turbulence analysis

Final Report, 1 Jan. - 31 Aug. 1977

CRANE, R. K.

Environmental Research and Technology, Inc., Concord, Mass.

Publication Date: Sep. 1977 149P.

Report No.: AD-A047740; AFGL-TR-77-0207

Contract No.: F19628-77-C-0059

Language: English

Country of Origin: United States Country of Publication: United States

Document Type: REPORT

Documents available from AIAA Technical Library

Other Availability: NTIS HC A07/MF A01

Journal Announcement: STAR7808

A model was developed to combine radiosonde observations with ultrasensitive well-calibrated radar measurements of clear air turbulence to provide estimates of two eddy parameters, the eddy dissipation rate and the eddy heat diffusion coefficient. The eddy parameters were obtained as volume averages over 1 km thick layers and time averages over several hours. The model was tested using simultaneously obtained radar measurements and pilot reports of turbulence intensity from a U-2 aircraft.

The model was also shown to be consistent with other reported radar and aircraft measurements. (Author (GRA))

Source of Abstract/Subfile: DTIC

31 (Item 31 from file: 108)

0863368 N77-30696

The effect of clear air turbulence on atmospheric mixing

Ph.D. Thesis

HECK, W. J.

Pennsylvania State Univ., University Park.

Publication Date: 1976 108P.

Language: English

Country of Origin: United States Country of Publication: United States

Document Type: THESIS

Documents available from AIAA Technical Library

Other Availability: Univ. Microfilms Order No. 77-9677

Journal Announcement: STAR7721

The contribution of small scale motions to the total vertical mixing in the lower stratosphere was determined from wind and temperature fluctuation statistics. Efficiency was estimated from the vertical heat flux, which was computed from the co-spectra of the vertical velocity and temperature. A parameterization scheme for clear air turbulence in the stratosphere and troposphere was also developed. (Dissert. Abstr.)

Source of Abstract/Subfile: Dissert. Abstr.

32 (Item 32 from file: 108)

0849456 N77-16606

Parameterization of clear-air turbulence

HECK, W. J.; PANOFSKY, H. A.

Pennsylvania State Univ., University Park.

In Deut. Wetterdienst Ann. of Meteorol. No. 11 p 72-73 (SEE N77-16587)

07-47)

Publication Date: 1976

Language: English

Country of Origin: United States Country of Publication: Germany,
Federal Republic of

Document Type: CONFERENCE PAPER

Documents available from AIAA Technical Library

Other Availability: NTIS HC A12/MF A01

Journal Announcement: STAR7707

As a result of an analysis of turbulence data near the tropopause and in the stratosphere, relations were developed between mean Reynolds stress and large-scale vertical wind shear for different heights. Similarly, heat flux is related to both temperature gradient and vertical wind shear. A parameterization scheme based on this analysis was tested on the General Circulation Model of NCAR. The changes produced by the turbulence are small but in the direction expected. (Author (ESA))

Source of Abstract/Subfile: ESA

34 (Item 34 from file: 108)
0812088 A77-20784

Energy dissipation within intermittent clear air turbulence patches

CADET, D. (Ecole Polytechnique, Palaiseau, Essonne, France)

Journal of the Atmospheric Sciences, vol. 34, Jan. 1977, p. 137-142.

Publication Date: Jan. 1977 14 Refs.

Language: English

Country of Origin: France Country of Publication: United States

Document Type: JOURNAL ARTICLE

Documents available from AIAA Technical Library

Journal Announcement: IAA7707

Mean dissipation rates of kinetic energy in the lower stratosphere are estimated from data obtained with an instrumented, superpressure, constant-level balloon launched to measure the vertical wind shear at 200 mb. The flight record shows that while the balloon was located above a mountainous region localized patches of turbulence were encountered. The record is divided into 20 periods. The structure function is calculated over each period and, under the hypothesis of an inertial subrange, the mean dissipation is in turn estimated over each period. Our calculations indicate that the mean dissipation rate of kinetic energy can vary to a great extent over distances as short as a few tens of kilometers. Thus, when the shear layer breaks down, the mean dissipation rate can be 10 times higher than just before or after the event. It can also be 100 times higher within moderately intense clear air turbulence patches than in very weak intensity turbulence zones. These results show the sporadic nature of mixing processes in the lower stratosphere associated with shearing instabilities. ((Author))

35 (Item 35 from file: 108)
0793012 N76-25717

atmospheric turbulence and vertical effective diffusion coefficients

ROSENBERG, N. W.; DEWAN, E. M.

Air Force Cambridge Research Labs., Hanscom AFB, Mass.

Publication Date: Sep. 1975 15P.

Report No.: AD-A019708; AFCRL-TR-75-0519; AFCRL-ERP-535
Contract No.: AF PROJ. 6687
Language: English
Country of Origin: United States Country of Publication: United States
Document Type: REPORT
Documents available from AIAA Technical Library
Other Availability: NTIS
Journal Announcement: STAR7616

Computations of the observed frequency distribution of the magnitudes of vertical shears of horizontal winds between 5 and 20 km altitude are reported. The probability distribution of turbulent layers for various values of vertical thickness is discussed. An effective vertical-diffusion coefficient, K_e , is estimated from a simple model using this empirical turbulence probability distribution. Specifically, the effect of clear-air turbulence upon vertical transport is calculated, using a model consisting of a vertical column of thin, randomly-spaced mixing (turbulent) layers separated by thick non-mixing atmospheric layers. (Author (GRA))

37 (Item 37 from file: 108)
0769003 A76-21419

Curvature of the wind profile in the troposphere versus regions of CAT and non-CAT in the stratosphere

POSSIEL, N. (U.S. Environmental Protection Agency, Research Triangle Park, N.C.); SCOGGINS, J. R. (Texas A & M University, College Station, Tex.)

Environmental Protection Agency, Research Triangle Park, N.C.
Monthly Weather Review, vol. 104, Jan. 1976, p. 57-62.

Publication Date: Jan. 1976 19 Refs.

Contract No.: NGR-44-001-081

Language: English

Country of Origin: United States Country of Publication: United States

Document Type: JOURNAL ARTICLE

Documents available from AIAA Technical Library

Journal Announcement: IAA7608

A discussion of the theoretical importance of the curvature of the wind profile to the amplitude of mountain waves is presented. Mechanisms favorable for clear air turbulence (CAT) are discussed in relation to such wave motions. It is shown that CAT encountered by the XB-70 aircraft in the stratosphere during expected mountain-wave conditions is related to the vertical gradient of curvature of the wind profile in the troposphere. Results indicate that 89% of the turbulent regions in the stratosphere occurred in expected mountain-wave areas and that 79% were located where the vertical gradient of curvature was positive in the 10-30,000 ft layer below. For the nonturbulent regions, 74% were outside expected mountain-wave areas and 98% of these occurred where the vertical gradient of curvature was negative. All the nonturbulent regions within expected mountain-wave areas occurred where the vertical gradient of curvature was negative. ((Author))

40 (Item 40 from file: 108)
0721530 A75-35416

The importance of the curvature of the wind profile in determining

regions of CAT and non-CAT (in stratosphere)

POSSIEL, N.; SCOGGINS, J. R. (Texas A & M University, College Station, Tex.)

In: Conference on Aerospace and Aeronautical Meteorology, 6th, El Paso, Tex., November 12-15, 1974, Preprints. (A75-35351 16-47) Boston, Mass., American Meteorological Society, 1974, p. 345-350.

Publication Date: 1974 19 Refs.

Contract No.: NGR-44001-081

Language: English

Country of Origin: United States Country of Publication: United States

Document Type: CONFERENCE PAPER

Journal Announcement: IAA7516

An investigation is conducted regarding the relationship between CAT and the curvature of the wind profile, taking into account cases of CAT encountered by the XB-70 in the stratosphere over the mountainous terrain of the western U.S. The results of the investigation show that the curvature of the wind profile is an important tropospheric variable in the determination of stratospheric CAT regions. These CAT regions are likely to occur in cases in which the curvature increases with height in the troposphere in areas when mountain waves are expected. (G.R.)

Source of Abstract/Subfile: AIAA/TIS

39 (Item 39 from file: 108)
0721531 A75-35417

Distinguishing between CAT and non-CAT areas by use of discriminant

function analysis (clear air turbulence)

CLARK, T. L.; SCOGGINS, J. R. (Texas A & M University, College Station, Tex.); COX, R. E. (Bechtel Power Corp., Houston, Tex.)

In: Conference on Aerospace and Aeronautical Meteorology, 6th, El Paso, Tex., November 12-15, 1974, Preprints. (A75-35351 16-47) Boston, Mass., American Meteorological Society, 1974, p. 351-356.

Publication Date: 1974 8 Refs.

Contract No.: NGR-44-001-081

Language: English

Country of Origin: United States Country of Publication: United States

Document Type: CONFERENCE PAPER

Journal Announcement: IAA7516

The investigation considered is concerned with a method in which a statistical approach is employed to determine algebraic functions involving selected synoptic-scale parameters which would indicate areas and altitudes of CAT in the stratosphere over the western U.S. The statistical approach selected is based on discriminant function analysis. The functions are determined from combinations of synoptic-scale parameters and stratospheric turbulence data. It was found in the investigation that there is a relationship between selected combinations of synoptic-scale parameters of the upper troposphere and lower stratosphere and stratospheric clear-air turbulence. (G.R.)

Source of Abstract/Subfile: AIAA/TIS

41 (Item 41 from file: 108)
0721529 A75-35415

Meteorological variables versus CAT in the stratosphere - A statistical approach

SCOGGINS, J. R. (Texas A & M University, College Station, Tex.)

In: Conference on Aerospace and Aeronautical Meteorology, 6th, El Paso, Tex., November 12-15, 1974, Preprints. (A75-35351 16-47) Boston, Mass., American Meteorological Society, 1974, p. 339-344.

Publication Date: 1974 20 Refs.

Contract No.: NGR-44-001-081

Language: English

Country of Origin: United States Country of Publication: United States

Document Type: CONFERENCE PAPER

Journal Announcement: IAA7516

Frequency distributions prepared from synoptic meteorological parameters at 300, 200, and 100 mb, associated with turbulent and non-turbulent areas encountered by the XB-70 airplane in the stratosphere (between 12 and 20 km), show that turbulence occurs more frequently than non-turbulence when the parameters exceed certain values. A procedure proposed for forecasting clear-air turbulence on the basis of the number of exceedances of limits of specified variables is verified for two flights of the XB-70 airplane. The procedure gives the geographical location of CAT regions, but further research is required before the altitude of CAT can be specified. (V.P.)

Source of Abstract/Subfile: AIAA/TIS

42 (Item 42 from file: 108)

0697894 A75-11779

The nonlinear behavior of atmospheric Kelvin waves

KOUSKY, V. E.; KOERMER, J. P. (Utah, University, Salt Lake City, Utah)

Journal of the Atmospheric Sciences, vol. 31, Oct. 1974, p. 1777-1783

Publication Date: Oct. 1974

Contract No.: NSF GA-29201

Language: English

Country of Origin: United States Country of Publication: United States

Document Type: JOURNAL ARTICLE

Documents available from AIAA Technical Library

Journal Announcement: IAA7501

The atmospheric Kelvin wave is modeled with nonlinear terms included. Forcing from below leads to a Kelvin wave similar to that observed. The nonlinear terms lead to an asymmetry in the wave, producing a zone of strong vertical shear in association with the westerly shear zone. Dissipation was not included in the model to limit the degree of asymmetry or buildup of vertical shear. Observational evidence indicates that clear-air turbulence eventually breaks out, thus causing the waves to suddenly dissipate. It is inferred that, at the time of dissipation, large amounts of westerly momentum are supplied to the mean flow and that this is responsible for the downward propagation of the westerly shear zone. (Author))

45 (Item 45 from file: 108)

0674418 N74-11274

Turbulence near the tropopause in the presence of mountain waves
BULDOVSKIY, G. S.

Air Force Systems Command, Wright-Patterson AFB, Ohio. Foreign Technology Div.

Publication Date: Aug. 1973 18P.

Translation Note: Transl. into ENGLISH from Analiz Meteorol. Uslovii dlya Aviatsii (USSR), no. 95, 1972 p 17-26

Report No.: AD-766577; FTD-MT-24-744-73

Language: English

Country of Origin: U.S.S.R. Country of Publication: United States

Document Type: JOURNAL ARTICLE; TRANSLATION

Documents available from AIAA Technical Library

Other Availability: NTIS

Journal Announcement: STAR7402

Investigation of the conditions for the development of turbulence near the tropopause, especially above a mountainous region, has great current significance in connection with the forthcoming flights of supersonic passenger aircraft. Near the tropopause there will be a transition zone to supersonic speed. The report discusses research on the conditions of turbulence near the tropopause above mountainous regions and simultaneous distribution of turbulence in the troposphere and the lower stratosphere. (GRA)

Source of Abstract/Subfile: DTIC

46 (Item 46 from file: 108)
0662972 A74-36554

Stratospheric mixing estimated from high-altitude turbulence measurements

LILLY, D. K. (National Center for Atmospheric Research, Boulder, Colo.); WACO, D. E.; ADELFGANG, S. I. (Lockheed-California Co., Burbank, Calif.)

Journal of Applied Meteorology, vol. 13, June 1974, p. 488-493. Research supported by the U.S. Department of Transportation.

Publication Date: Jun. 1974 25 Refs.

Language: English

Country of Origin: United States Country of Publication: United States

Document Type: JOURNAL ARTICLE

Documents available from AIAA Technical Library

Journal Announcement: IAA7417

An estimate is made of the vertical diffusion coefficient for heat due to eddy mixing associated with small-scale turbulence. The estimate is made as a function of underlying terrain, with means deduced for the earth as a whole and for the geographical region of North America and Greenland. The values obtained are believed to be about equally valid for ozone or other more-or-less passive scalar quantities, and may be of suitable magnitude for incorporation into three-dimensional numerical simulation models of the stratosphere. (M.V.E.)

Source of Abstract/Subfile: AIAA/TIS

47 (Item 47 from file: 108)
0636015 N73-33522

Analysis of meteorological conditions for aviation (Meteorological and weather effects on aircraft landings and flights along air lanes and stratospheric wind effects on supersonic transports)

ABRAMOVICH, K. G., ed.

Joint Publications Research Service, Arlington, Va.
Publication Date: Sep. 1973 69P.
Translation Note: Transl. into ENGLISH of the publ. "Analiz
Meteorologicheskikh Usloviy dlya Aviatsii" Leningrad, Gidrometeoizdat,
1972 63 p

Report No.: JPRS-60114

Language: English

Country of Origin: U.S.S.R. Country of Publication: United States

Document Type: BOOK; TRANSLATION

Documents available from AIAA Technical Library

Other Availability: NTIS

Journal Announcement: STAR7324

Results are presented of studies conducted on weather phenomena which can limit aircraft landings and flights along air lanes. The effects of the spatial variability of the wind in the stratosphere on the accuracy of maintaining a flight trajectory by a supersonic transport at a given altitude are also discussed.

48 (Item 48 from file: 108)
0618372 N73-15451

Some results from experimental investigations of turbulence in the troposphere and stratosphere (Statistical correlations between clear air turbulence and macrosynoptic processes in troposphere and stratosphere)

PINUS, N. Z.; SHUR, G. N.

Air Force Systems Command, Wright-Patterson AFB, Ohio. Foreign Technology Div.

Publication Date: Sep. 1972 33P.

Translation Note: Transl. into ENGLISH from Beitr. Geophysik (Leipzig), v. 79, no. 5, 1970 p 363-378

Report No.: AD-750514; FTD-HC-23-538-72

Language: English

Country of Origin: Germany, Peoples Democratic Republic of

Country of Publication: United States

Document Type: REPORT; TRANSLATION

Documents available from AIAA Technical Library

Other Availability: NTIS

Journal Announcement: STAR7306

After introductory comments on the significance of turbulence research in terms of modern aviation, the authors investigate the character of turbulence on the scales concerned here. The sources and depressions of turbulent energy as well as the forms of energy spectra are discussed here in connection with various atmospheric conditions. On the basis of aircraft observations, data is presented on the appearance and character of turbulence in the stratosphere and on the level of the tropopause. Finally, the results are given for a statistical investigation of the tie-in between turbulence and macrosynoptic processes, from which a synoptic-statistical method for the prediction of clear-air turbulence is derived. (Author (GRA))

Source of Abstract/Subfile: DTIC

49 (Item 49 from file: 108)
0610811 A73-43339

Internal gravity wave-mean wind interaction.

HOLTON, J. R. (Washington, University, Seattle, Wash.); LINDZEN, R. S. (Harvard University, Cambridge, Mass.)

Science, vol. 182, Oct. 5, 1973, p. 85, 86.

Publication Date: Oct. 1973 6 Refs.

Language: English

Country of Origin: United States Country of Publication: United States

Document Type: JOURNAL ARTICLE

Documents available from AIAA Technical Library

Journal Announcement: IAA7323

Bekofske and Liu (1972) have demonstrated that the interaction of a vertically propagating internal gravity wave with the background wind shear near a critical level can increase the background wind shear sufficiently to satisfy the criterion for the Kelvin-Helmholtz instability. Numerical calculations quite similar to those conducted by Bekofske and Liu have previously been reported by Lindzen and Holton (1968) in their study of the quasi-biennial oscillation in the mean zonal wind in the equatorial stratosphere. Lindzen and Holton, however, considered a multichromatic wave source. Conditions for the occurrence of a quasi-steady balance are discussed. (G.R.)

Source of Abstract/Subfile: AIAA/TIS

50 (Item 50 from file: 108)
0607526 A73-40054

Objective cross-section analyses by Hermite polynomial interpolation on isentropic surfaces.

SHAPIRO, M. A.; HASTINGS, J. T. (National Center for Atmospheric Research, Boulder, Colo.)

Journal of Applied Meteorology, vol. 12, Aug. 1973, p. 753-762.

Publication Date: Aug. 1973 17 Refs.

Language: English

Country of Origin: United States Country of Publication: United States

Document Type: JOURNAL ARTICLE

Documents available from AIAA Technical Library

Journal Announcement: IAA7321

An objective cross-section analysis scheme based upon Hermite polynomial interpolation on surfaces of constant potential temperature is shown to define frontal-scale horizontal and vertical gradients of potential temperature and geostrophic wind, using synoptic upper air sounding observations as input data. The objective routine was also found applicable to analysis of the thermal properties of oceanic frontal zones from bathythermograph sounding data. Calculations of potential vorticity, vertical wind shear, and Richardson number suggest the usefulness of the objective scheme for real-time specification of regions of stratospheric-tropospheric mass exchange and probable locations of jet-stream, frontal-zone-related, clear-air turbulence. ((Author))

57 (Item 57 from file: 108)
0522985 A72-14676

Fine structure of the medium and upper stratosphere: Detection of clear air turbulence - Application to flights anticipated for supersonic

transport aircraft (Stratospheric circulation and air temperature horizontal and vertical distribution, discussing CAT at supersonic transport heights)

Structure fine de la stratosphere moyenne et elevee: Detection de la turbulence en ciel clair - Application aux vols envisages pour les avions de transport supersoniques

BARBE, G. D. (Etablissement d'Etudes et de Recherches de la Meteorologie Nationale, Paris, France)

Societe Meteorologique Francaise and American Meteorological Society, Colloque sur la Meteorologie Aeronautique, Paris and Orly, France, May 24-26, 1971, Paper. 37 p. In French.

Publication Date: May 1971 14 Refs.

Language: French

Country of Origin: France Country of Publication: France

Document Type: CONFERENCE PAPER

Documents available from AIAA Technical Library

Journal Announcement: IAA7204

Discussion of the vertical and horizontal distribution of the circulation and air temperature of the stratosphere, which in certain cases is very turbulent, more so, it appears, than the troposphere. Clear air turbulence (CAT) can be encountered at altitudes several km above the levels flown by present-day transports. Temperature variations amounting to several degrees have been measured within air layers about 100 m thick and 10 km long. In certain cases, this temperature variation affects thicker layers. A certain correlation appears to exist between CAT and the irregularities measured either in a vertical or horizontal plane involving temperature and the horizontal wind vector. (F.R.L.)

Source of Abstract/Subfile: AIAA/TIS

59 (Item 59 from file: 108)
0515929 N71-36398

Relation between stratosphere turbulence causing aircraft buffeting and

the vertical distribution of meteorological parameters (Relation between turbulence in stratosphere causing aircraft buffeting, and vertical distribution of meteorological parameters calculated from radiosonde data)

svyaz turbulentnosti v stratosfere, vyzyvayushchey boltanku samoletov, s vertikalnym raspredeleniyem meteorologicheskikh parametrov

BULDOVSKIY, G. S.

Translation Consultants Ltd., Arlington, Va.

Place of Publication: Washington Publisher: NASA

Publication Date: Oct. 1971 18P. 255 Refs.

Translation Note: Transl. into ENGLISH from Gidrometeoizdat (USSR), no. 70, 1970 p 79-92

Report No.: NASA-TT-F-13981

Contract No.: NASW-2038

Language: English

Country of Origin: U.S.S.R. Country of Publication: United States

Document Type: REPORT; TRANSLATION

Documents available from AIAA Technical Library

Other Availability: NTIS

Journal Announcement: STAR7123

62 (Item 62 from file: 108)
0505413 N71-25746

Study of clear sky turbulence in the stratosphere (Clear air turbulence in stratosphere and effects on weather formation, atmospheric physics, and supersonic flights)

VINNICHENKO, N. K.; et al.

Joint Publications Research Service, Washington, D. C.

Publication Date: May 1971 12P.

Translation Note: TRANSL. INTO ENGLISH FROM TR. TSENTR. AEROLOG. OBSERV. /MOSCOW/, NO. 100, 1970 P 86-98

Report No.: JPRS-53133

Language: English

Country of Origin: U.S.S.R. Country of Publication: United States

Document Type: JOURNAL ARTICLE; TRANSLATION

Documents available from AIAA Technical Library

Other Availability: NTIS AVAIL- NTIS

Journal Announcement: STAR7114

Source of Abstract/Subfile: NASA STIF

63 (Item 63 from file: 108)
0480430 A71-36008

An analysis of heat-, momentum-transport, and spectra for clear air

turbulence in mid- stratosphere (Clear air turbulence in midstratosphere, analyzing heat and momentum transports and temperature fluctuations spectra)

GEBHARD, J. B. /UTAH U., SALT LAKE CITY, UTAH/.; KAO, S.-K.

PURE AND APPLIED GEOPHYSICS, VOL. 88, NO. 5, P. 180-185.

Publication Date: 1971 12 Refs.

Language: English

Document Type: JOURNAL ARTICLE

Documents available from AIAA Technical Library

Journal Announcement: IAA7118

Source of Abstract/Subfile: AIAA/TIS

68 (Item 68 from file: 108)
0434810 N70-23165

The aerodynamics of atmospheric shear flow Conference proceedings (Aerodynamics of atmospheric shear flows conference emphasizing clear air turbulence, stratosphere, wind tunnel simulation, and environmental effects)

Advisory Group for Aerospace Research and Development, Paris (France).

Publication Date: Feb. 1970 539P.

Presentation Note: PRESENTED AT FLUID DYN. PANEL SPECIALISTS' MEETING, MUNICH, 15-17 SEP. 1969

Report No.: AGARD-CP-48

Language: MULTIPLE; MOSTLY IN ENGLISH, PARTLY IN FRENCH

Country of Origin: France

Document Type: REPORT; CONFERENCE PROCEEDINGS

Documents available from AIAA Technical Library

Other Availability: NTIS

Journal Announcement: STAR7010

69 (Item 69 from file: 108)
0418154 A70-42619

igh altitude clear air turbulence probability based on temperature profiles and rawinsonde ascensional rates (Stratospheric clear air turbulence probability based on vertical temperature gradients and rawinsonde ascensional rates)

PROPHET, D. T. /LOCKHEED-CALIFORNIA CO., BURBANK, CALIF./.
MONTHLY WEATHER REVIEW, VOL. 98, P. 704- 707.

Publication Date: Sep. 1970

Language: English

Country of Publication: United States

Document Type: JOURNAL ARTICLE

Documents available from AIAA Technical Library

Journal Announcement: IAA7022

Source of Abstract/Subfile: AIAA/TIS

70 (Item 70 from file: 108)
0406138 A70-30603

Stratospheric clear air turbulence models (Stratospheric CAT-internal

wave relationship, using aircraft and radiosonde HICAT measurements)

MITCHELL, F. A. /LOCKHEED-CALIFORNIA CO., BURBANK, CALIF./.

Place of Publication: BOSTON Publisher: AMERICAN METEOROLOGICAL SOCIETY

Publication Date: 1970 8P.

Publication Note: CONFERENCE SPONSORED BY THE AMERICAN METEOROLOGICAL SOCIETY AND THE AMERICAN INST. OF AERONAUTICS AND ASTRONAUTICS.

Presentation Note: IN- NATIONAL CONFERENCE ON AEROSPACE METEOROLOGY, 4TH, LAS VEGAS, NEV., MAY 4-7, 1970, PREPRINTS. P. 375-382. /A70-30551 14-20/

Language: English

Country of Publication: United States

Document Type: CONFERENCE PROCEEDINGS

Documents available from AIAA Technical Library

Journal Announcement: IAA7014

Source of Abstract/Subfile: AIAA/TIS

73 (Item 73 from file: 108)
0397893 A70-22357

An energy budget for a layer of stratospheric CAT (Stratospheric CAT layer energy budget analysis, considering energy shear feeding, buoyant extraction and frictional dissipation)

DUTTON, J. A. /PENNSYLVANIA STATE U., UNIVERSITY PARK, PA./.

RADIO SCIENCE, VOL. 4, P. 1137-1142.

Publication Date: Dec. 1969 6 Refs.

Presentation Note: /INTERNATIONAL UNION OF RADIO SCIENCE, COLLOQUIUM ON SPECTRA OF METEOROLOGICAL VARIABLES, STOCKHOLM, SWEDEN, JUN. 9-19, 1969/

Contract No.: NSF GA-1595X

Language: English

Country of Origin: International Organization Country of Publication: United States

Document Type: JOURNAL ARTICLE

Documents available from AIAA Technical Library

Journal Announcement: IAA7009
Source of Abstract/Subfile: AIAA/TIS

74 (Item 74 from file: 108)
0394124 A70-18588

Clear air turbulence in the stratosphere above a squall line (
Stratospheric clear air turbulence over squall line, discussing turbulence
over thunderstorms)

PROPHET, D. T. /LOCKHEED-CALIFORNIA CO., BURBANK, CALIF./.

Place of Publication: BOSTON Publisher: AMERICAN METEOROLOGICAL SOCIETY

Publication Date: 1969 4P.

Presentation Note: IN- THUNDERSTORMS AND THUNDERSTORM PHENOMENA,
AMERICAN

METEOROLOGICAL SOCIETY, CONFERENCE ON SEVERE LOCAL STORMS, 6TH, CHICAGO,
ILL., APR. 8-10, 1969, PREPRINTS. P. 363-366. /A70-18567 06-20/

Language: English

Country of Publication: United States

Document Type: CONFERENCE PROCEEDINGS

Documents available from AIAA Technical Library

Journal Announcement: IAA7006

Source of Abstract/Subfile: AIAA/TIS

78 (Item 78 from file: 108)

Power spectrum, structure function, vertical wind shear, and
turbulence

in troposphere and stratosphere. (Vertical wind shears, structure
functions, turbulence and power spectra for transverse velocity
fluctuations in troposphere and stratosphere, noting clear air turbulence)

ESSENWANGER, O. /U.S. ARMY, MISSILE COMMAND, PHYSICAL SCIENCES LAB.,
REDSTONE ARSENA, ALA./; REITER, E. R. /COLORADO STATE U., FORT COLLINS,
COLO./.

ARCHIV FUER METEOROLOGIE, GEOPHYSIK UND BIOKLIMATOLOGIE, SERIE
A-METEOROLOGIE UND GEOPHYSIK, VOL. 18, NO. 1-2, P. 17-24.

Publication Date: 1969 19 Refs.

Language: English

Country of Origin: United States Country of Publication: United States

Document Type: JOURNAL ARTICLE

Documents available from AIAA Technical Library

Journal Announcement: IAA6920

Source of Abstract/Subfile: AIAA/TIS

80 (Item 80 from file: 108)
0344822 A69-33736

Meteorological analysis of clear air turbulence in the stratosphere. (
Meteorological analysis of stratospheric clear air turbulence flights,
discussing vertical temperature structure in terms of wave motion and
turbulence intensity)

MITCHELL, F. A.; PROPHET, D. T. /LOCKHEED AIRCRAFT CORP.,
LOCKHEED-CALIFORNIA CO., BURBANK, CALIF./.

Place of Publication: NEW YORK Publisher: PLENUM PRESS

Publication Date: 1969 39P.

Presentation Note: IN- CLEAR AIR TURBULENCE AND ITS DETECTION, BOEING CO., SYMPOSIUM, SEATTLE, WASH., AUG. 14-16, 1968, PROCEEDINGS. P. 144- 182.
<A69-33732 17-20<

Language: English

Country of Publication: United States

Document Type: CONFERENCE PROCEEDINGS

Documents available from AIAA Technical Library

Journal Announcement: IAA6917

Source of Abstract/Subfile: AIAA/TIS

81 (Item 81 from file: 108)
0344818 A69-33732

Clear Air Turbulence and its Detection, Boeing Company, Symposium, Seattle, Wash., August 14-16, 1968, Proceedings. (Clear air turbulence and detection - Conference, Seattle, August 1968)

GOLDBURG, A.; PAO, H.-H.

Place of Publication: NEW YORK Publisher: PLENUM PRESS

Publication Date: 1969 555P.

Presentation Note: CLEAR AIR TURBULENCE AND ITS DETECTION, BOEING CO., SYMPOSIUM, SEATTLE, WASH., AUG. 14- 16, 1968, PROCEEDINGS.

Language: English

Country of Origin: United States Country of Publication: United States

Document Type: CONFERENCE PROCEEDINGS

Documents available from AIAA Technical Library

Journal Announcement: IAA6917

Source of Abstract/Subfile: AIAA/TIS

82 (Item 82 from file: 108)
0340823 A69-29737

Meteorological conditions for the onset of aircraft bumpiness in the stratosphere (Stratospheric turbulence producing bumpiness up to 18 km developing at levels characterized by abrupt changes in vertical temperature gradients)

Meteorologicheskie usloviia vozniknoveniia boltanki samoletov v stratosfere

BULDOVSKII, G. S.

Place of Publication: LENINGRAD Publisher: GIDROMETEOIZDAT

Publication Date: 1968 13P. 13 Refs.

Publication Note: IN- AVIATION FORECASTING OF THE CLOUD COVER, HIGH-ALTITUDE WIND, AND TURBULENCE <PROGNOZIROVANIE DLIA AVIATSII OBLACHNOSTI, VETRA NA VYSOTAKH I TURBULENTNOSTI>. EDITED BY K. G. ABRAMOVICH. <A69-29734 14-20< /GLAVNOE UPRAVLENIE

GIDROMETEOROLOGICHESKOE

SLUZHBY SSSR, GIDROMETEOROLOGICHESKII NAUCHNO- ISSLEDOVATELSKII TSENTR, TRUDY, NO. 35/, P. 36-48.

Language: Russian

Country of Origin: U.S.S.R.

Document Type: ANALYTIC OF COLLECTED WORK; TRANSLATION

Documents available from AIAA Technical Library

Journal Announcement: IAA6914

84 (Item 84 from file: 108)

0309738 N68-26807

Atmospheric temperature gradients related to clear air turbulence in the upper troposphere and lower stratosphere (Relationship between atmospheric temperature gradients and clear air turbulence of lower atmosphere)

KADLEC, P. W.

Eastern Air Lines, Inc., Miami, Fla.

Publication Date: Nov. 1967 16P.

Report No.: NASA-CR-91055

Contract No.: NAS4-1194

Language: English

Country of Origin: United States Country of Publication: United States

Document Type: REPORT

Documents available from AIAA Technical Library

Other Availability: NTIS

Journal Announcement: STAR6815

90 (Item 90 from file: 108)
0091893 A65-22595

Relationships between turbulence in limpid air and the "quality" of solar image (Solar image quality related to tropospheric and lower stratospheric jet stream turbulence)

relazioni fra turbolenza in aria limpida e "qualita" dell'immagine solare

AFFRONTI, F.; TORRISI, S.

RIVISTA DI METEOROLOGIA AERONAUTICA, VOL. 25, JAN.-MAR. 1965, P. 5-16. 9

REFS. IN ITALIAN.

Publication Date: Mar. 1965

Language: Italian

Document Type: JOURNAL ARTICLE

Documents available from AIAA Technical Library

Journal Announcement: IAA6512

Source of Abstract/Subfile: AIAA/TIS

91 (Item 91 from file: 108)
0088506 A65-19208

The nature of clear air turbulence. (Clear air turbulence characteristics and formation possibly due to large wind shears)

REITER, E. R. /COLORADO STATE U., FORT COLLINS, COLO./.

/ORGANISATION SCIENTIFIQUE ET TECHNIQUE INTERNATIONALE DU VOL A VOILE, CONGRESS, 9TH, JUNIN, ARGENTINA, FEB. 1963/ AERO-REVUE, VOL. 40, MAR. 1965, P. 150-152. 5 REFS.

Publication Date: Mar. 1965

Language: English

Document Type: JOURNAL ARTICLE

Documents available from AIAA Technical Library

Journal Announcement: IAA6509

Source of Abstract/Subfile: AIAA/TIS

92 (Item 92 from file: 108)
0086121 A65-16822

On the analysis of clear air turbulence by use of rawinsonde data. (
Clear air turbulence in upper troposphere and lower stratosphere via
rawinsonde data)

ENDLICH, R. M.; MANCUSO, R. L. /STANFORD RESEARCH INST., MENLO PARK,
CALIF./.

MONTHLY WEATHER REVIEW, VOL. 93, JAN. 1965, P. 47-58. 14 REFS.

Publication Date: Jan. 1965

Contract No.: CWB-10624

Language: English

Country of Origin: United States Country of Publication: United States

Document Type: JOURNAL ARTICLE

Documents available from AIAA Technical Library

Journal Announcement: IAA6507

Source of Abstract/Subfile: AIAA/TIS

95 (Item 95 from file: 108)
0024155 N63-10499

(Atmospheric microstructure & its bearing on clear- air turbulence)
REITER, E. R.

COLORADO STATE U., FORT COLLINS THE ATMOSPHERIC MICRO-STRUCTURE AND ITS
BEARING ON CLEAR-AIR TURBULENCE /CAT/ A PRELIMINARY REPORT ELMAR R.
REITER

OCT. 1962 23 P 16 REFS /CONTRACT N 189/188/55120A/ /TECH. PAPER 39,
CER62ERR62, NWRF 15-1062-069/

Publication Date: Oct. 1962

Report No.: CER-62ERR62; NWRF15-1062-069

Contract No.: N189/188/-55120A

Language: English

Document Type: REPORT

Documents available from AIAA Technical Library

Journal Announcement: STAR6301

96 (Item 96 from file: 108)
0017130 N62-11173

(Study of severe clear-air turbulence)
REITER, E. R.

COLORADO STATE U. RESEARCH FOUNDATION, FORT COLLINS A CASE STUDY OF
SEVERE CLEAR-AIR TURBULENCE. SCIENTIFIC REPORT. ELMAR R. REITER. MAR. 1962.
16 P. 10 REFS. /ATMOSPHERIC SCIENCE TECH. PAPER 30, CER62ERR20,
NWRF-15-0362-057/ /CONTRACT N 189/188/ 55120 A/

Publication Date: Mar. 1962

Report No.: CER62ERR20; NWRF-15-0362-057

Contract No.: N189/188/-55120A

Language: English

Country of Origin: United States Country of Publication: United States

Document Type: REPORT

Documents available from AIAA Technical Library

Journal Announcement: STAR6204

119 (Item 3 from file: 144)
03693656 PASCAL No.: 82-0210122

FRESNEL SCATTERING MODEL FOR THE SPECULAR ECHOES OBSERVED BY VHF RADAR

GAGE K S; BALSLEY B B; GREEN J L

NATIONAL OCEANIC ATMOSPHER. ADMINISTRATION/BOULDER CO 80303,USA

Journal: RADIO SCI., 1981, 16 (6) 1447-1453

ISSN: 0048-6604 Availability: CNRS-550D

No. of Refs.: 21 REF.

Document Type: P (SERIAL) ; A (ANALYTIC)

Country of Publication: USA

Language: ENGLISH

PRESENTATION D'UN NOUVEAU MODELE EXPLICITANT L'AMPLITUDE IMPORTANTE DES ECHOS ANISOTROPES PROVENANT DES REGIONS STABLES DE LA TROPOSPHERE ET DE LA STRATOSPHERE. LE MODELE SE RAPPORTE A LA DIFFUSION A PARTIR D'UNE COMPOSANTE DE FOURIER DEMI-LONGUEUR D'ONDE D'UNE STRUCTURE FINE HORIZONTALEMENT COHERENTE DANS L'INDICE DE REFRACTION DES ONDES RADIO, A L'INTERIEUR D'UNE ZONE VERTICALE DE DIMENSIONS FINIES. CE MECANISME D'ECHO EST DENOMME "DIFFUSION DE FRESNEL". APPLICATION DU MODELE A LA SIMULATION DE L'AMPLITUDE D'ECHOS RADARS EN UTILISANT DES RESULTATS DE RADIOSONDAGE DE TEMPERATURE

122 (Item 6 from file: 144)

00843923 PASCAL No.: 76-0159555

METEOROLOGICAL VARIABLES VS CAT IN THE *STRATOSPHERE*. A STATISTICAL

APPROACH.

SCOGGINS JR

TEXAS A & M UNIV., COLLEGE STATION, TEX.

Journal: J. AIRCR., 1975, 12 (7) 567-571

Availability: CNRS-11415

No. of Refs.: 20 REF.

Document Type: P (SERIAL) ; A (ANALYTIC)

Country of Publication: USA

Language: ENGLISH

DES AIRES DE TURBULENCE EN CIEL CLAIR RENCONTREE ENTRE 12 ET 20 KM D'ALTITUDE, AU COURS DE 46 VOLS DU XB-70 AU-DESSUS DE LA PARTIE OCCIDENTALE DES ETATS-UNIS, ONT ETE RELIEES AUX PARAMETRES SYNOPTIQUES MESURES (VENT, T,...) ET CALCULES (VORTICITE, ADVECTION DE T, TAUX DE VARIATION, FONCTION DU TEMPS,...). LA DISTRIBUTION RELATIVE DE FREQUENCE DES PARAMETRES ASSOCIES SOIT A LA TURBULENCE SOIT A LA NON-TURBULENCE, A ETE EXAMINEE POUR 300, 200 ET 100 MB. ON MONTRE QUE LES PARAMETRES SONT ASSOCIES A LA TURBULENCE DANS LA STRATOSPHERE LORSQUE CERTAINES LIMITES DES VARIABLES SONT DEPASSEES. LES RESULTATS SUGGERENT QUE LES AIRES DE TURBULENCE RENCONTREES AU COURS DE VOLS SUPERSONIQUES DANS LA STRATOSPHERE AU-DESSUS

DE LA PARTIE OCCIDENTALE DES ETATS-UNIS, PEUVENT ETRE DETERMINEES A PARTIR DES DONNEES SYNOPTIQUES. PROPOSITION D'UNE METHODE DE PREVISION

EXPERIMENT

102 (Item 6 from file: 6)
253934 NTIS Accession Number: AD-735 419
Stratospheric Turbulence and Temperature Gradients Measured by an RB-57F.

Coldscan Flights 57 to 92

MacPherson, J. I. ; Morrissey, E. G.

National Aeronautical Establishment Ottawa (Ontario)

Corp. Source Codes: 240300

Report No.: NAE-LR-551; NRC-12318

Oct 71 86p

Journal Announcement: GRAI7205

NTIS Prices: PC A05 MF A01

Through most of the period from January 1969 to June 1971, a USAF RB-57F high altitude weather reconnaissance aircraft has carried special NRC instrumentation to measure and record stratospheric turbulence and horizontal temperature gradients encountered on routine flights at altitudes from 40,000 to 65,000 feet. The main purpose of this cooperative program, named 'Coldscan', was to collect data on atmospheric conditions at altitudes to be flown by the supersonic transports. Data are presented on the correlation between measured stratospheric turbulence and horizontal temperature gradients, on the altitude and geographical distributions of the turbulence and temperature change encounters, and on the positions of the recorded incidents relative to the jet stream. (Author)

105 (Item 9 from file: 6)
214377 NTIS Accession Number: AD-720 955
Stratospheric Turbulence and Temperature Gradients Measured by an Rb-57F.

Coldscan Flights 19 to 56

(Aeronautical rept.)

MacPherson, J. I. ; Morrissey, E. G.

National Aeronautical Establishment Ottawa (Ontario)

Corp. Source Codes: 240300

Report No.: NAE-LR-542; NRC-11774

Nov 70 81p

Journal Announcement: GRAI7110

NTIS Prices: PC A05 MF A01

Since January 1969, a USAF RB-57F high altitude weather reconnaissance aircraft has carried a special NRC instrumentation system to measure and record stratospheric turbulence and horizontal temperature gradients encountered at altitudes from 40,000 to above 60,000 feet. The chief purpose of this co-operative program, named 'Coldscan', is to collect data on atmospheric conditions at altitudes to be flown by the supersonic transports. To date, 57 data flights have been flown, covering 82,000 nautical miles of the central and western United States, Ontario, and the Pacific Ocean south of Panama. This is the second Coldscan data report and includes a summary of the results of all 57 flights, in addition to detailed accounts of a selection of 20 events from Flights 19 through 56 that showed significant temperature gradients or light to moderate turbulence. These presentations include time histories of the recorded variables, flight tracks showing event positions, and meteorological

analyses. (Author)

106 (Item 10 from file: 6)
168609 NTIS Accession Number: AD-702 160
The Scientific Objectives, Philosophy, and Management of the Mocat Project
(Final rept. 10 Jan-15 Apr 69)
Dutton, John A.
Air Force Flight Dynamics Lab Wright-Patterson AFB Ohio
Corp. Source Codes: 012070
Report No.: AFFDL-TR-69-96
Dec 69 141p
Journal Announcement: USGRDR7009
NTIS Prices: PC A07 MF A01
Contract No.: AF-682E

The time has come for a thorough investigation of the physics of clear air turbulence (CAT) in order to fulfill the needs of both the aeronautical and scientific communities for improved understanding of this phenomenon. The report shows how the MOCAT project can be organized to fulfill this objective, and that there is sufficient understanding of CAT so that the project can be planned for maximum effectiveness. Present knowledge about CAT shows that it is likely that it is a manifestation of the Kelvin-Helmholtz instability. The correspondence of the implications of this hypothesis and the tendency for CAT to occur in internal fronts (baroclinic layers) is emphasized. A detailed analysis of the instrumentation requirements combines acceptable error in the final measurements and known characteristics of CAT to determine acceptable RMS errors in the basic measurements such as airspeed, pitch, yaw, and roll angles, and inertial platform velocities. An organizational structure which will simplify project management and increase the likelihood of success is proposed. The plan attempts to delineate responsibility for segments of the program according to the natural divisions which occur in the scientific and engineering communities. (Author)

107 (Item 11 from file: 6)
114373 NTIS Accession Number: AD-676 081
Undulance and Turbulence in Stably Stratified Media
Pao, Yih-Ho
Boeing Scientific Research Labs Seattle Wash Flight Sciences Lab
Corp. Source Codes: 400753
Report No.: D1-82-0742
Aug 68 30p
Journal Announcement: USGRDR6823
NTIS Prices: PC A03 MF A01

The origin and the structure of undulance and turbulence in stably stratified media are investigated through theoretical reasoning and laboratory experiments. The mechanisms for generating turbulence in stably stratified media are linked with the mechanisms for generating vorticity - shear and stratification. The dual role of stable stratification -- the capability for generating and attenuating turbulence -- is pointed out. The turbulence induced by stable stratification is evidenced in two experimental results: (1) turbulent rotors in the lee of a barrier in a stably stratified fluid, and (2) the breaking of traveling internal waves on a sloping surface. The ability of stable stratification to generate

turbulence is also indicated from an exact solution for an inviscid stably stratified flow past a barrier. The structure of undulance and turbulence in stably stratified media is investigated in a stratified salt water towing tank, with schlieren photographs, quartz-coated hot-film probes, and single electrode conductivity probes. The schlieren photographs show clearly the collapse of a turbulent wake and the attenuation of turbulence by stable stratification. Auto-correlations and -spectra for the streamwise turbulent velocity field and for the turbulent concentration field are obtained. From the measured correlations and spectra, the combined wave-turbulence behavior is clearly shown, and the turbulence is strongly anisotropic. (Author)

108 (Item 12 from file: 6)
098109 NTIS Accession Number: AD-667 222
Observations of Stratospheric Clear-Air Turbulence and Mountain Waves
over the Sierra Nevada Mountains: An Analysis of the U-2 Flights of 13-14 May, 1964
(Final rept. 14 Jun 64-14 Sep 67)
Helvey, Roger A.
California Univ Los Angeles Dept of Meteorology
Corp. Source Codes: 072271
Report No.: AFCRL-68-0001
Dec 67 93p
Journal Announcement: USGRDR6811
Report on 'Meso-Scale Calculations' project.
NTIS Prices: PC A05 MF A01
Contract No.: AF 19(628)-4146; AF-8604; 860402
Data obtained from a specially-instrumented U-2 aircraft have been used to relate clear-air turbulence with mountain wave structure, observed during two research flights in the stratosphere over the Sierra Nevada Mountains on 13 and 14 May, 1964. The several cases of severe turbulence encountered took place in regions immediately downstream of wave troughs, in area of decreased static stability and slower wind speeds associated with the prevailing upwind tilt of the waves. An expression for the Richardson number is obtained which incorporates modifications imposed upon flow through stationary disturbances such as mountain waves. (Author)

109 (Item 1 from file: 2)
02384865 INSPEC Abstract Number: A85023903
Title: Simultaneous measurements of temperature and velocity fluctuations
within *clear* *air* *turbulence* layers: analysis of the estimate of dissipation rate by remote sensing techniques
Author(s): Barat, J.; Bertin, F.
Author Affiliation: Paris VI Univ., France
Journal: Journal of the Atmospheric Sciences vol.41, no.9 p.1613-19
Publication Date: 1 May 1984 Country of Publication: USA
CODEN: JAHSAK ISSN: 0022-4928
Language: English Document Type: Journal Paper (JP)
Treatment: Experimental (X)
Abstract: Estimates of dissipation rate from remote-sensing techniques measuring the structure parameter $C_{n^2}/2$ of density turbulent fluctuations assume a relationship between $C_{n^2}/2$ and the

dissipation rate ϵ . In order to obtain a precise test of this relation, in situ observations are of major importance. The authors present in this paper the first simultaneous in situ measurements of these parameters. The analysis of data shows that the models of turbulence used in the radar literature are not always fully justified and that the estimate of dissipation rate may be underestimated. (23 Refs)

112 (Item 4 from file: 2)

01115547 INSPEC Abstract Number: A77086968

Title: The effect of *clear*-air *turbulence* on a model of the general circulation of the atmosphere

Author(s): Heck, W.J.; Panofsky, H.A.; Bender, M.A.

Author Affiliation: Dept. of Meteorology, Pennsylvania State Univ., University Park, PA, USA

Journal: Contributions to Atmospheric Physics vol.50, no.1-2 p. 89-97

Publication Date: 1977 Country of Publication: West Germany

CODEN: BPYAAY ISSN: 0005-8173

Conference Title: International Conference on Simulation of Large-Scale Atmospheric Processes

Conference Date: 30 Aug.-4 Sept. 1976 Conference Location: Hamburg, West Germany

Language: English Document Type: Conference Paper (PA); Journal Paper (JP)

Treatment: Theoretical (T); Experimental (X)

Abstract: Mixing coefficients due to clear-air turbulence are estimated from turbulence observations from aircraft, and from large-scale dissipation estimates from the large-scale energy budgets. Maximum coefficients occur near middle-latitude jet streams, and eddy viscosity there is of order of $10 \text{ m}^2/\text{s}$; eddy conductivity is estimated to be about ten times smaller. These coefficients are introduced into the 12-layer general circulation model of the National Center of Atmospheric Research. They produce an apparently significant, though small, reduction in maximum speed of the jet and a reduction in eddy energy. Further, the stratospheric polar-night jet is produced at about the correct location with about the correct intensity. (14 Refs)

113 (Item 5 from file: 2)

01073909 INSPEC Abstract Number: A77056676

Title: Energy dissipation within intermittent *clear* *air* *turbulence* patterns

Author(s): Cadet, D.

Author Affiliation: Lab. de Meteorologie Dynamique, Ecole Polytechnique, Palaiseau, France

Journal: Journal of the Atmospheric Sciences vol.34, no.1 p.137-42

Publication Date: Jan. 1977 Country of Publication: USA

CODEN: JAHSAP ISSN: 0022-4928

Language: English Document Type: Journal Paper (JP)

Treatment: Theoretical (T); Experimental (X)

Abstract: Mean dissipation rates of kinetic energy in the lower stratosphere are estimated from data obtained with an instrumented, superpressure, constant-level balloon launched to measure the vertical wind

shear at 200 mb. The flight record shows that while the balloon was located above a mountainous region localized patches of turbulence were encountered. (14 Refs)

114 (Item 6 from file: 2)
00763011 INSPEC Abstract Number: A75038978
**Title: 1-16 Hz infrasound associated with *clear* *air*
*turbulence***
predictors
Author(s): Posmenter, E.S.
Author Affiliation: City Univ. New York, Bronx, NY, USA
Conference Title: Infra-Sons. (Infra-Sound) p.197-228
Publisher: Nat. Sci. Res. Centre, Paris, France
Publication Date: 1974 Country of Publication: France 432 pp.
Conference Date: 24-27 Sept. 1973 Conference Location: Paris, France
Language: English Document Type: Conference Paper (PA)
Treatment: Experimental (X)
Abstract: The general nature of this higher frequency infrasound has been explored and the essential finding of the study has been the association of this infrasound with clear air turbulence in the lower stratosphere. (15 Refs)

116 (Item 8 from file: 2)
00299314 INSPEC Abstract Number: A71062655
**Title: Cloud and synoptic parameters associated with *clear* *air*
*turbulence***
Author(s): Ball, J.T.
Issued by: Center Environment & Man Inc., Hartford, CT, USA
Publication Date: Aug. 1970 Country of Publication: USA 72 pp.
Report Number: NASA-111778 Contract Number: NAS12-699
Availability: NTIS, Springfield, VA 22151, USA
Language: English Document Type: Report (RP)
Treatment: Experimental (X)
Abstract: Research was initiated to determine relationships between clear air turbulence (CAT) in the stratosphere and upper troposphere and meteorological variables, circulation features and cloud characteristics. For this purpose, a total of 372 cases of CAT occurrence and nonoccurrence were analyzed using aircraft instrumented reports of CAT in the 45000-70000 ft layer as obtained by the US Air Force in Project HICAT from 1966 through 1968. Light to moderate or more intense CAT occurs frequently when the vertical temperature profile about the level of interest is irregular and includes both strong inversions and layers in which the temperature decreases rapidly with height. Consistent numerical relationships were determined for a number of meteorological variables describing this condition. Implementation of these results for the development of CAT detection instrumentation is discussed. The analysis of circulation features showed that significant stratospheric CAT was associated with large horizontal temperature gradients at upper-level surfaces. Cloud characteristics associated with significant turbulence were cirrus bands and streaks, a well-defined frontal cloud band, transverse wave clouds, and cumulonimbus clouds.

117 (Item 1 from file: 144)
07327967 PASCAL No.: 86-0328410

Preliminary results on a study of *stratospheric* aerosol loading by means of lidar analysis of long- and short-time fluctuations

STEFANUTTI L; MORANDI M; CASTAGNOLI F; RADICATI B

IROE, Firenze 50127, Italy

Gruppo nazionale per la fisica dell'atmosfera e dell'oceano. Congresso. 1 (Roma) 1984

Journal: Nuovo cimento. C, 1985, 8 (6) 714-726

ISSN: 0390-5551 Availability: CNRS-178C

No. of Refs.: dissem.

Document Type: P (Serial); C (Conference Proceedings) ; A (Analytic)

Country of Publication: Italy

Language: ENGLISH Summary Language: Italian; Russian

Poursuite lidar des aerosols consecutifs a l'eruption du El Chicho'n. Les fluctuations sont observees en relation avec des turbulences en air clair et des ondes de gravite

8 (Item 8 from file: 108)

1405123 N85-32548

Millstone Hill radar: Capabilities for S/T observations

LORIOT, G. B.

Northeast Radio Observatory Corp., Westford, Mass. Haystack Observatory. Haystack Observatory.

In International Council of Scientific Unions Middle Atmosphere Program. Handbook for MAP. Vol. 14 p 362 (SEE N85-32466 21-46)

Publication Date: Dec. 1984

Language: English

Country of Origin: United States Country of Publication: United States

Document Type: CONFERENCE PAPER

Documents available from AIAA Technical Library

Other Availability: NTIS HC A17/MF A01; also available from SCOSTEP Secretariat, Illinois Univ., 1406 West Green Street, Urbana, Ill. 61801

Journal Announcement: STAR8521

During the past several years, the 440-MHz radar at Millstone Hill has been modified to detect coherent echoes from clear-air turbulence in the stratosphere/troposphere (S/T) over the altitude range 4-25 km. Two distinct modes of data acquisition have been developed, and data reduction programs have been completed for one of these modes. This mode (I-mode) transmits a 10 microsec (1.5 km) pulse on the fully steerable antenna. Typically, the antenna is set at a low elevation angle (e.g., 15 deg.) to reduce the altitude resolution to approximately 1 km., and power spectra are collected at some 40 range gates. The antenna may be scanned in azimuth to obtain the total wind vector, held fixed to monitor wave motion, or scanned in elevation to monitor the horizontal extent of the turbulent activity. This steerability gives Millstone a flexible system to focus on localized events, such as lee waves or convective storms. An additional advantage at low elevations is the relatively large Doppler shift of the signal, since the LOS velocity contains a large component of the horizontal velocity. This shift separates the turbulence signal sufficiently far from the ground clutter to allow the spectral moments to be readily inferred. Some 500 hours of S/T I-mode data have been reduced to geophysical parameters, and reside on a data base at Millstone Hill. (G.L.C.)

Source of Abstract/Subfile: NASA STIF

9 (Item 9 from file: 108)

1377035 A85-28701

Observations of vertical motions in the troposphere and lower stratosphere using three closely-spaced ST radars

BALSLEY, B. B.; ECKLUND, W. L.; CARTER, D. A. (NOAA, Aeronomy Laboratory, Boulder, CO); CROCHET, M. (Laboratoire de Sondages Electromagnetiques de l'Environnement, Toulon, France; NOAA, Aeronomy Laboratory, Boulder, CO); RIDDLE, A. C.; GARELLO, R. (Colorado, University; NOAA, Aeronomy Laboratory, Boulder, CO)

IN: Conference on Radar Meteorology, 21st, Edmonton, Alberta, Canada, September 19-23, 1983, Preprints (A85-28676 12-47). Boston, MA, American Meteorological Society, 1983, p. 148-152. Research supported by the Centre National de la Recherche Scientifique, Institut National d'Astronomie et de Geophysique and NSF.

Publication Date: 1983 5 Refs.

Language: English

Country of Origin: United States Country of Publication: United States

Document Type: CONFERENCE PAPER

Documents available from AIAA Technical Library

Journal Announcement: IAA8512

Continuous observations of vertical winds, performed during the Alpine Experiment by a network of three stratosphere-troposphere radars, are discussed. The vertical velocity spectra were acquired between 3 and 20 km of altitude at 750-m intervals with time resolution of 1 min, covering quiet and active-wind periods extending from 2 to 200 minutes. It was established that the winds measured by the vertically directed beams are truly vertical; the increased slope of the vertical spectra, observed during high wind activity, suggests, however, that the antennas are registering a component of the horizontal flow. Finally, the increased coherence between sites at periods longer than about 30 min indicates that a considerable organized wave activity is present at longer periods. (L.T.)

Source of Abstract/Subfile: AIAA/TIS

11 (Item 11 from file: 108)

1362307 A85-19419

On the measurement of the turbulence dissipation rate from rising balloons

BARAT, J.; COT, C.; SIDI, C. (CNRS, Service d'Aeronomie, Verrieres-le-Buisson, Essonne, France)

Journal of Atmospheric and Oceanic Technology (ISSN 0739-0572), vol. 1, Sept. 1984, p. 270-275.

Publication Date: Sep. 1984 20 Refs.

Language: English

Country of Origin: France Country of Publication: United States

Document Type: JOURNAL ARTICLE

Documents available from AIAA Technical Library

Journal Announcement: IAA8507

The feasibility of turbulence measurements below a rising balloon is analyzed. From a typical case study it is shown that a helisonde hung below a large diameter balloon can resolve the vertical profile of the dissipation rate in the troposphere and stratosphere. The potential effect of the balloon wake is examined, and the results emphasize the importance

of a wind-shear measurement in order to interpret the basic data properly.
(Author)

Source of Abstract/Subfile: AIAA/TIS

16 (Item 16 from file: 108)

1227102 A83-12956

Initial results from the use of ionic anemometers under stratospheric balloons - Application to the high-resolution analysis of stratospheric motions

BARAT, J. (CNRS, Service d'Aeronomie, Verrieres-le-Buisson, Essonne, France)

Journal of Applied Meteorology, vol. 21, Oct. 1982, p. 1489-1496.

Publication Date: Oct. 1982 17 Refs.

Language: English

Country of Origin: France Country of Publication: United States

Document Type: JOURNAL ARTICLE

Documents available from AIAA Technical Library

Journal Announcement: IAA8302

A new kind of sounding is described. The relative horizontal wind between a balloon and a gondola located below it is measured by means of high-resolution anemometers. The integration along the vertical of the relative wind gives the vertical profile of the atmospheric flow. Two examples are presented. During the sounding, clear air turbulence (CAT) is detected. An example of the CAT structure in the middle stratosphere is presented. Laboratory and in-flight calibrations of the anemometers are outlined. ((Author))

18 (Item 18 from file: 108)

1136878 A82-12128

Observations of clear air turbulence and winds with the Millstone Hill radar

WATKINS, B. J.; WAND, R. H. (Haystack Observatory, Westford, MA)

(International Symposium on Middle Atmosphere Dynamics and Transport, University of Illinois, Urbana, IL, July 28-Aug. 1, 1980.) Journal of Geophysical Research, vol. 86, Oct. 20, 1981, p. 9605-9614.

Publication Date: Oct. 1981 13 Refs.

Contract No.: NSF ATM-77-12916

Language: English

Country of Origin: United States Country of Publication: United States

Document Type: JOURNAL ARTICLE; CONFERENCE PAPER

Documents available from AIAA Technical Library

Journal Announcement: IAA8202

The Millstone Hill radar operates at a frequency of 440 MHz with a peak pulse power in the range from 1 to 2 MW. The pulse length used in all experiments to date has been 10 microseconds corresponding to a range resolution of 1.5 km. The antenna is a 150-foot diameter steerable dish with 1 deg beamwidth. Initial experiments with the Millstone Hill radar indicate it to be a valuable tool for studying turbulence and winds in the troposphere and lower stratosphere. Because of its steerable antenna, the radar is capable of examining the spatial structure of turbulence as well as making continuous wind observations. While this capability has not yet been fully developed, it is considered important for aiding the understanding of wavelike observations in the data. (G.R.)

Source of Abstract/Subfile: AIAA/TIS

23 (Item 23 from file: 108)
1094841 A81-34007

The external scale of clear air turbulence derived from the vertical ozone profile - Application to vertical transport measurement

BARAT, J.; AIMEDIEU, P. (CNRS, Service d'Aeronomie, Verrieres-le-Buisson, Essonne, France)

Journal of Applied Meteorology, vol. 20, Mar. 1981, p. 275-280.

Publication Date: Mar. 1981 15 Refs.

Language: English

Country of Origin: France Country of Publication: United States

Document Type: JOURNAL ARTICLE

Documents available from AIAA Technical Library

Journal Announcement: IAA8115

Clear-air turbulence encountered in the stratosphere and the transport of atmospheric constituents along the vertical are analyzed, and the vertical ozone profiles obtained by a high-resolution stratospheric ozonometer are studied. The instrument took measurements during ascent and descent using the chemiluminescence of the ozone/ethylene reaction. The intensity of the light emitted is measured by a photomultiplier and the output signal expressed as the number of counts/unit of time, is linearly proportional to the ozone concentration for a given density of the medium. Results show that the layered structure of turbulence zones is reflected on the vertical ozone profile by alternating thin layers closely approaching mixture equilibrium and thicker layers in which the vertical concentration gradient reaches very high values. The diffusion coefficient can be estimated from the structure functions of concentration inhomogeneities. While it was possible to determine the external scale of the turbulence field and the extension of the inertial region, direct investigation of turbulent movement of short wavelengths was not achieved. However, the validity of the proposed method was confirmed and a global investigation of the transport term, leading to an improvement in parameterization for the modeling of the stratosphere is suggested. (E.B.)

Source of Abstract/Subfile: AIAA/TIS

24 (Item 24 from file: 108)
1063476 N80-26937

The exchange of chemical constituents between the stratosphere and troposphere through turbulent mixing processes within tropopause folds

SHAPIRO, M. A.

National Center for Atmospheric Research, Boulder, Colo.

In WMO The Long-Range Transport of Pollutants and its Relation to Gen. Circulation Including Stratospheric/Tropospheric Exchange Processes p 377-383 (SEE N80-26888 17-45)

Publication Date: 1979

Language: English

Country of Origin: United States Country of Publication: International Organization

Document Type: CONFERENCE PAPER

Documents available from AIAA Technical Library

Other Availability: NTIS HC A19/MF A01

Journal Announcement: STAR8017

Small scale turbulent mixing processes within the jet stream associated tropopause folds were studied as a mechanism for chemical exchange across

the tropopause. By combining the turbulent motion sensing capability of the Sabreliner research aircraft with fast response ozone and condensation nuclei measurements, the turbulent vertical flux of stratospheric ozone and tropospheric condensation nuclei across the tropopause was evaluated. Analysis of the flight data show the characteristic downward intrusion of high ozone concentration air into the folded portion of the tropopause. The tropopause fold was filled with planetary boundary layer concentrations of condensation nuclei, which when taken together with the ozone data provide evidence for the coexistence of chemical trace constituents of both tropospheric and stratospheric origin within the region of tropopause folding. The observations suggest that tropopause folds are mixing regions whose chemical characteristics lie somewhere in between those of the troposphere and the stratosphere, and that turbulent mixing is of first order importance as a mechanism for stratospheric-tropospheric chemical exchange in the vicinity of tropopause folds. (Author (ESA))

Source of Abstract/Subfile: ESA

27 (Item 27 from file: 108)

0951973 A79-27590

VHF Doppler radar studies of CAT in the troposphere and lower stratosphere

GREEN, J. L.; GAGE, K. S.; VANZANDT, T. E. (NOAA, Aeronomy Laboratory, Boulder, Colo.)

In: Conference on Atmospheric Environment of Aerospace Systems and Applied Meteorology, New York, N.Y., November 14-16, 1978, Preprints. (A79-27563 10-47) Boston, Mass., American Meteorological Society, 1978, p. 159-164.

Publication Date: 1978 25 Refs.

Language: English

Country of Origin: United States Country of Publication: United States

Document Type: CONFERENCE PAPER

Journal Announcement: IAA7910

The paper is concerned with the applicability of the VHF Doppler radar to the detection of clear-air turbulence (CAT). Some preliminary comparisons are presented between pilot reports of turbulence and vertical profiles of turbulence intensity derived from observations of the Sunset radar. This is the first VHF Doppler radar specifically designed to observe the troposphere and stratosphere. The detection of CAT previously reported for powerful UHF radars is shown to be feasible through the use of the VHF Doppler radar. A technique is presented to quantify the radar echo intensity in terms of the eddy dissipation rate (used to determine the intensity of atmospheric turbulence). The magnitudes of eddy dissipation rate reported are in good agreement with the range of eddy dissipation rates evaluated by other methods. (S.D.)

Source of Abstract/Subfile: AIAA/TIS

29 (Item 29 from file: 108)

0918196 N78-17634

Stratospheric turbulence analysis

Final Report, 1 Jan. - 31 Aug. 1977

CRANE, R. K.

Environmental Research and Technology, Inc., Concord, Mass.

Publication Date: Sep. 1977 149P.

Report No.: AD-A047740; AFGL-TR-77-0207

Contract No.: F19628-77-C-0059
Language: English
Country of Origin: United States Country of Publication: United States
Document Type: REPORT
Documents available from AIAA Technical Library
Other Availability: NTIS HC A07/MF A01
Journal Announcement: STAR7808

A model was developed to combine radiosonde observations with ultrasensitive well-calibrated radar measurements of clear air turbulence to provide estimates of two eddy parameters, the eddy dissipation rate and the eddy heat diffusion coefficient. The eddy parameters were obtained as volume averages over 1 km thick layers and time averages over several hours. The model was tested using simultaneously obtained radar measurements and pilot reports of turbulence intensity from a U-2 aircraft.

The model was also shown to be consistent with other reported radar and aircraft measurements. (Author (GRA))

Source of Abstract/Subfile: DTIC

30 (Item 30 from file: 108)
0869828 A78-13111

A comparison of estimated and directly measured turbulent heat fluxes in the lower stratosphere

HECK, W. (NASA, Goddard Institute for Space Studies, New York, N.Y.)
National Aeronautics and Space Administration. Goddard Inst. for Space Studies, New York.

Monthly Weather Review, vol. 105, Oct. 1977, p. 1337-1340

Publication Date: Oct. 1977

Contract No.: NSF CD-73-00215-A01

Language: English

Country of Origin: United States Country of Publication: United States

Document Type: JOURNAL ARTICLE

Documents available from AIAA Technical Library

Journal Announcement: IAA7802

The contribution of small-scale motions to the vertical heat flux in the lower stratosphere is determined from wind and temperature fluctuation statistics obtained during the High Altitude Clear Air Turbulence investigation. Analysis of the cospectra suggests a horizontal wavelength of 3 km as the appropriate long-wave cutoff of small-scale motion. With this scale restriction, the measured vertical heat fluxes are in good agreement with the values of heat flux estimated by Lilly et al. (1974) from the kinetic energy dissipation rate. Hence, the hypothesis of Lilly et al. for estimating heat flux from the dissipation rate is considered to be reliable. It follows that, in the lower stratosphere, subsynoptic vertical transport is small compared to large-scale transport. ((Author))

33 (Item 33 from file: 108)
0812932 A77-21628

Arecibo middle atmosphere experiment (stratospheric and mesospheric UHF radar echo sounding)

ASO, T.; KATO, S. (Kyoto University, Uji, Japan); HARPER, R. M. (Arecibo Ionospheric Observatory, Arecibo, P.R.)

Geophysical Research Letters, vol. 4, Jan. 1977, p. 10-12.

Publication Date: Jan. 1977 7 Refs.

Language: English

Country of Origin: Japan Country of Publication: United States

Document Type: JOURNAL ARTICLE

Documents available from AIAA Technical Library

Journal Announcement: IAA7708

An experiment was performed using the powerful radar at Arecibo to look for stratospheric and mesospheric echoes in the UHF frequency band. Strong echoes were returned from the stratospheric region, whereas no distinct returns were obtained from mesospheric heights. These results, when compared to those reported for the VHF radar at Jicamarca, support wavenumber dependences of the scattering mechanisms, such that scattering due to neutral air turbulence should be more effective at UHF frequencies than at VHF in the stratosphere, while the reverse should be true in the mesosphere. The results suggest the feasibility of utilizing the present UHF incoherent scatter radar for remote sensing of winds in the stratosphere. ((Author))

38 (Item 38 from file: 108)

0724004 A75-37890

Experimental study of the structure of the turbulence field in the middle stratosphere

Etude experimentale de la structure du champ de turbulence dans la moyenne stratosphere

BARAT, J. (CNRS, Service d'Aeronomie, Verrieres-le-Buisson, Essonne, France)

Academie des Sciences (Paris), Comptes Rendus, Serie B - Sciences Physiques, vol. 280, no. 22, June 9, 1975, p. 691-693. In French.

Publication Date: Jun. 1975 5 Refs.

Language: French

Country of Origin: France Country of Publication: France

Document Type: JOURNAL ARTICLE

Documents available from AIAA Technical Library

Journal Announcement: IAA7518

A device is described permitting in-situ measurements of microscale turbulence in the stratosphere. The apparatus consists of two groups of triaxial anemometers suspended under a balloon that is large compared to the turbulence scale. Preliminary experimental results are presented, with emphasis on the vertical distribution of turbulence layers between 22 and 27 km altitude as measured on October 12, 1974. The results can be applied to the analysis of the influence of pollutants on the ozone layer. (S.J.M.)

Source of Abstract/Subfile: AIAA/TIS

39 (Item 39 from file: 108)

0721531 A75-35417

Distinguishing between CAT and non-CAT areas by use of discriminant

function analysis (clear air turbulence)

CLARK, T. L.; SCOGGINS, J. R. (Texas A & M University, College Station, Tex.); COX, R. E. (Bechtel Power Corp., Houston, Tex.)

In: Conference on Aerospace and Aeronautical Meteorology, 6th, El Paso, Tex., November 12-15, 1974, Preprints. (A75-35351 16-47) Boston, Mass., American Meteorological Society, 1974, p. 351-356.

Publication Date: 1974 8 Refs.

Contract No.: NGR-44-001-081

Language: English

Country of Origin: United States Country of Publication: United States

Document Type: CONFERENCE PAPER

Journal Announcement: IAA7516

The investigation considered is concerned with a method in which a statistical approach is employed to determine algebraic functions involving selected synoptic-scale parameters which would indicate areas and altitudes of CAT in the stratosphere over the western U.S. The statistical approach selected is based on discriminant function analysis. The functions are determined from combinations of synoptic-scale parameters and stratospheric turbulence data. It was found in the investigation that there is a relationship between selected combinations of synoptic-scale parameters of the upper troposphere and lower stratosphere and stratospheric clear-air turbulence. (G.R.)

Source of Abstract/Subfile: AIAA/TIS

44 (Item 44 from file: 108)

0679378 N74-16291

Stratospheric vertical wind shear (applied to clear air turbulence and Eole balloons)

etude du cisaillement vertical du vent dans la stratosphere rapport final

Final Report

MOREL, P.; CADET, D.

Centre National de la Recherche Scientifique, Paris (France). Lab. de Meteorologie Dynamique.

Publication Date: Dec. 1972 27P.

Contract No.: DGRST-70-0-2171

Language: French

Country of Origin: France Country of Publication: France

Document Type: REPORT

Documents available from AIAA Technical Library

Other Availability: NTIS

Journal Announcement: STAR7407

Stratospheric vertical wind shear was studied by means of propeller type, differential anemometers and simplified fluxgate magnetometers onboard high altitude, long duration balloon flights. The instrument package is detailed. Ten flights were performed, two of which yielded round-the-earth data at one second intervals during blocks of four to six hours. The RMS intensity (0.02/sec) and horizontal rotation of the wind shear in the lower stratosphere are determined exhibiting the stratified flow structure with a vertical scale length of about 100 meters. Application of these results to the anomalous turbulent diffusion exhibited by the Eole balloons is discussed.

Application of the anemometer to the Essor balloon is discussed. (ESRO)

Source of Abstract/Subfile: ESA

51 (Item 51 from file: 108)

0593259 A73-25785

Mountain waves and CAT encountered by the XB-70 in the stratosphere.

SCOGGINS, J. R. (Texas A & M University, College Station, Tex.);

INCROCCI, T. P. (USAF, Washington, D.C.; Global Weather Central, Omaha, Neb.)

Journal of Aircraft, vol. 10, Mar. 1973, p. 172-180.

Publication Date: Mar. 1973 20 Refs.

Contract No.: NGR-44-001-081

Language: English

Country of Origin: United States Country of Publication: United States

Document Type: JOURNAL ARTICLE

Documents available from AIAA Technical Library

Journal Announcement: IAA7311

The data from 36 XB-70 flights conducted over the mountainous regions of the western United States together with rawinsonde data were used to investigate relationships between conditions favorable for mountain waves and clear air turbulence. Profiles for the Scorer parameter and the gradient Richardson number were evaluated from the rawinsonde data. The Scorer parameter and the gradient Richardson number profiles were computed on those days when the XB-70 flew, and these results compared to model profiles and related to the reported turbulence. Ascent rate profiles of rawinsonde balloons were analyzed from which the presence of mountain or lee waves was inferred. ((Author))

52 (Item 52 from file: 108)

0571884 N72-28304

Fine structure of the middle and high stratosphere. Detection of clear air turbulence. Application to flights envisaged from supersonic transport aircraft (Wind, temperature, and clear air turbulence in middle and upper stratosphere)

BARBE, G. D.; et al.

National Lending Library for Science and Technology, Boston Spa (England).

Publication Date: 1972 19P.

Translation Note: Transl. into ENGLISH from the publ. "'French/American Meteorological Societies Joint Meeting" Paris, 1971

Report No.: NLL-M-22438-(5828.4F)

Language: English

Country of Origin: France Country of Publication: United Kingdom

Document Type: CONFERENCE PAPER; TRANSLATION

Documents available from AIAA Technical Library

Other Availability: Natl. Lending Library, Boston Spa, Engl.: 2 NLL photocopy coupons

Journal Announcement: STAR7219

Wind and fine scale temperature soundings were carried out under a variety of experimental conditions. Clear air turbulence measurements observations were made using Canberra and Concorde aircraft. The results are presented in the form of curves giving the distributions as a function of altitude, height, wind speed, and temperature. (K.P.D.)

Source of Abstract/Subfile: NASA STIF

53 (Item 53 from file: 108)

0571238 N72-27638

Meteorological assistance for the Concorde trial flights (Weather predictions for Concorde test flights and problems of forecasting stratospheric temperature and clear air turbulence)

CAZALE, H. R.

National Lending Library for Science and Technology, Boston Spa (England).

Publication Date: 1972 17P.

Translation Note: Transl. into ENGLISH from the publ. "'French/American Meteorological Societies' Joint Meeting" Paris, 1971 p 1-19

Report No.: NLL-M-22439-(5828.4F)

Language: English

Country of Origin: France Country of Publication: United Kingdom

Document Type: CONFERENCE PAPER; TRANSLATION

Documents available from AIAA Technical Library

Other Availability: Natl. Lending Library, Boston Spa, Eng.: 2 NLL photocopy coupons

Journal Announcement: STAR7218

The weather predictions for the Concorde test flights are discussed for the prototype and first subsonic flights in the lower atmospheric layers, the subsonic and transonic flights at altitudes between 500 and 200 mb, and the supersonic flights reaching to 100 mb and at a speed of Mach 2. The problems of predicting clear air turbulence and of predicting temperatures at 100 mb and 70 mb with sufficient fine detail and accuracy are described.

The general conclusion is that meteorological help has played an important role in successive phases of the SST tests, and that increasing meteorological assistance will be requested. (N.E.N.)

Source of Abstract/Subfile: NASA STIF

54 (Item 54 from file: 108)

0563591 N72-19682

CAT investigations in the stratosphere (Observations of clear air turbulence in stratosphere by high altitude subsonic aircraft)

VINNICHENKO, N. K.; PINUS, N. Z.; SUR, G. N.

National Lending Library for Science and Technology, Boston Spa (England).

Publication Date: 1971 11P.

Translation Note: Transl. into ENGLISH from Tr. Tsentr. Aerolog. Observ. (Moscow), v. 100, 1970 p 86-98

Report No.: NLL-M-22069-(5828.4F)

Language: English

Country of Origin: U.S.S.R. Country of Publication: United Kingdom

Document Type: JOURNAL ARTICLE; TRANSLATION

Documents available from AIAA Technical Library

Other Availability: Natl. Lending Library, Boston Spa, Engl.: 1 NLL photocopy coupon

Journal Announcement: STAR7210

Results of experimental studies of turbulence in the stratosphere on a specially equipped high altitude subsonic aircraft flying over mountains and plains are considered. Data on the geometry and structure of zones of turbulence are obtained. In the stratosphere, as in the troposphere, there are local zones of turbulence, but the extent and depth of these zones are much less in the stratosphere. Zones of turbulence in the stratosphere are considerably more intense over mountains than over plains, because the stratosphere is made turbulent by breaking mountain waves. Examples of the distribution of zones of turbulence with respect to the tropopause and the level of maximum wind are given. Correlation and spectral characteristics of CAT in the stratosphere are also given. Some correlation functions have a harmonic tail which is not damped; this suggests that there are wave motions in the stratosphere. Power spectra of the horizontal wind component in the stratosphere, covering the meso-scale and micro-scale regions, are also given. (Author)

55 (Item 55 from file: 108)
0537176 A72-28867

Meteorological parameters versus CAT encountered in the stratosphere by

the XB-70 airplane. (Synoptic meteorological parameters vs CAT encountered in stratosphere by XB-70 airplane, presenting frequency distributions and probability tables)

SCOGGINS, J. R. (Texas A & M University, College Station, Tex.)

In: International Conference on Aerospace and Aeronautical Meteorology, 1st, Washington, D.C., May 22-26, 1972, Preprints. (A72-28801 13-20) Boston, American Meteorological Society, 1972, p. 361-366.

Publication Date: 1972 18 Refs.

Contract No.: NGR-44-001-081

Language: English

Country of Origin: United States Country of Publication: United States

Document Type: CONFERENCE PAPER

Journal Announcement: IAA7213

Frequency distributions prepared from synoptic meteorological parameters associated with turbulent and nonturbulent conditions encountered by the XB-70 aircraft at altitudes generally between 12 and 20 km in the stratosphere show that turbulence is associated with certain ranges or critical values of the parameters. Certain combinations of the variables are associated with turbulence for at least one-fourth to one-third of the observations. (G.R.)

Source of Abstract/Subfile: AIAA/TIS

56 (Item 56 from file: 108)
0530747 A72-22438

Temperature gradients in stratospheric turbulence. (Horizontal temperature variations relation to stratospheric CAT based on U-2 flight data)

WACO, D. E. (Lockheed-California Co., Burbank, Calif.)

Journal of Applied Meteorology, vol. 11, Feb. 1972, p. 99-107.

Publication Date: Feb. 1972 25 Refs.

Language: English

Country of Origin: United States Country of Publication: United States

Document Type: JOURNAL ARTICLE

Documents available from AIAA Technical Library

Journal Announcement: IAA7209

Use of data obtained from U-2 HICAT flights to relate the magnitudes of horizontal temperature changes to flight conditions. The empirical findings can be used in estimating the effectiveness of aircraft-borne sensors which rely on temperature measurements for the remote detection of clear air turbulence. Gust velocity changes of at least 20 ft/sec occurred in all but one of 68 turbulence encounters in which temperature changes were 3 C or higher, and in only 13 of 97 cases with changes of less than 1C. Although short-period temperature variations were generally small during smooth flight and increased in magnitude during rougher flight, exceptions were noted. Large horizontal temperature changes were observed during smooth flight in the vicinity of severe turbulence and during occasional flights where the temperature changed appreciably over shallow vertical layers. Small changes were sometimes noted during moderate turbulence when the vertical temperature structure was nearly isothermal. ((Author))

58 (Item 58 from file: 108)
0519591 A72-11282

An analysis of conditions associated with an occurrence of stratospheric CAT. (Stratospheric CAT relationships to baroclinic zones and Richardson number examined from aircraft observed cross sections data)

DELAY, R. D. (USAF, Air Weather Service); DUTTON, J. A. (Pennsylvania State University, University Park, Pa.)

Journal of the Atmospheric Sciences, vol. 28, Oct. 1971, p. 1272-1279.

Publication Date: Oct. 1971 10 Refs.

Contract No.: NSF 1595X

Language: English

Country of Origin: United States Country of Publication: United States

Document Type: JOURNAL ARTICLE

Documents available from AIAA Technical Library

Journal Announcement: IAA7201

Cross sections of potential temperature, wind shear, and gradient Richardson number were constructed from data obtained during a Project HICAT flight and analyzed to determine the relationship to clear air turbulence in the stratosphere. CAT was found to be associated with strong baroclinic zones and with a critical value of the Richardson number of 0.25. Energy budgets for five patches of turbulence associated with this outbreak of stratospheric clear air turbulence were also examined, and found to balance within 4-18% of the total rate of shear production. (Author))

60 (Item 60 from file: 108)
0513267 N71-33671

Clear air turbulence in the Australian stratosphere (Meteorological flight search for clear air turbulence in stratosphere above Australia, 1966)

RIDER, C. K.; THOMSON, M. R.

Department of Supply, Melbourne (Australia). AERONAUTICAL RESEARCH LABS.

Publication Date: Jan. 1971 14P.

Publication Note: ITS STRUCT. AND MATER. NOTE 362

Language: English

Country of Origin: Australia Country of Publication: Australia

Document Type: REPORT

Documents available from AIAA Technical Library

Other Availability: NTIS AVAIL- NTIS

Journal Announcement: STAR7120

61 (Item 61 from file: 108)
0510969 N71-31351

An investigation of the relationships between mountain-wave conditions

and clear air turbulence encountered by the XB-70 airplane in the stratosphere (XB-70 aircraft for investigating and predictive XB-70 aircraft for investigating and predicting mountain waves)

INCROCCI, T. P.; SCOGGINS, J. R.

Texas A&M Univ., College Station.

Place of Publication: WASHINGTON Publisher: NASA

Publication Date: Jul. 1971 40P.

Report No.: NASA-CR-1878; H-679

Contract No.: NGR-44-001-081
Language: English
Country of Origin: United States Country of Publication: United States
Document Type: REPORT
Documents available from AIAA Technical Library
Other Availability: NTIS AVAIL- NTIS
Journal Announcement: STAR7118

72 (Item 72 from file: 108)
0403631 A70-28095
Vertical extent of turbulence in clear air above the tops of thunderstorms (Stratospheric clear air turbulence /CAT/ vertical extent above thunderstorm graphically represented)
PROPHET, D. T. /LOCKHEED-CALIFORNIA CO., BURBANK, CALIF./.
JOURNAL OF APPLIED METEOROLOGY, VOL. 9, P. 320, 321.
Publication Date: Apr. 1970
Language: English
Country of Publication: United States
Document Type: JOURNAL ARTICLE
Documents available from AIAA Technical Library
Journal Announcement: IAA7012
Source of Abstract/Subfile: AIAA/TIS

77 (Item 77 from file: 108)
0381249 N69-36983
Research to determine cloud and synoptic parameters associated with clear air turbulence Interim report (Clear air turbulence in stratosphere and troposphere)
BALL, J. T.; COOLEY, D. S.
Travelers Research Center, Inc., Hartford, Conn.
Publication Date: Jul. 1969 78P.
Report No.: NASA-CR-86229; REPT-7496-362
Contract No.: NAS12-699
Language: English
Country of Origin: United States Country of Publication: United States
Document Type: REPORT
Documents available from AIAA Technical Library
Other Availability: NTIS
Journal Announcement: STAR6921

79 (Item 79 from file: 108)
0344824 A69-33738
The Colorado lee wave program. (Lee waves and orographic wind phenomena in Rocky Mountains near Boulder, noting stratospheric standing gravity waves and turbulence sampled by HI-CAT U-2)
LILLY, D. K.; TOUTENHOOFD, W. /NATIONAL CENTER FOR ATMOSPHERIC RESEARCH, BOULDER, COLO./.
Place of Publication: NEW YORK Publisher: PLENUM PRESS
Publication Date: 1969 14P.
Presentation Note: IN- CLEAR AIR TURBULENCE AND ITS DETECTION, BOEING CO., SYMPOSIUM, SEATTLE, WASH., AUG. 14-16, 1968, PROCEEDINGS. P. 232- 245.
<A69-33732 17-20<

Language: English

Country of Origin: United States Country of Publication: United States

Document Type: CONFERENCE PROCEEDINGS

Documents available from AIAA Technical Library

Journal Announcement: IAA6917

Source of Abstract/Subfile: AIAA/TIS

81 (Item 81 from file: 108)

0344818 A69-33732

Clear Air Turbulence and its Detection, Boeing Company, Symposium,

Seattle, Wash., August 14-16, 1968, Proceedings. (Clear air turbulence and detection - Conference, Seattle, August 1968)

GOLDBURG, A.; PAO, H.-H.

Place of Publication: NEW YORK Publisher: PLENUM PRESS

Publication Date: 1969 555P.

Presentation Note: CLEAR AIR TURBULENCE AND ITS DETECTION, BOEING CO., SYMPOSIUM, SEATTLE, WASH., AUG. 14- 16, 1968, PROCEEDINGS.

Language: English

Country of Origin: United States Country of Publication: United States

Document Type: CONFERENCE PROCEEDINGS

Documents available from AIAA Technical Library

Journal Announcement: IAA6917

Source of Abstract/Subfile: AIAA/TIS

86 (Item 86 from file: 108)

0292370 A68-45280

Recent investigations of clear air turbulence in the USSR. (Clear air turbulence research in U.S.S.R., discussing energy spectra measurements and effects on aircraft at various heights in troposphere and stratosphere)

VINNICHENKO, N. K. /TSENTRAL'NAIA AEROLOGICHESKAIA OBSERVATORIIA, DOLGO-PRUDNAYA, USSR/.

Place of Publication: SEATTLE, WASH. Publisher: BOEING SCIENTIFIC RESEARCH LABS.

Publication Date: 1968 6P.

Presentation Note: IN- BOEING SCIENTIFIC RESEARCH LABS., SYMPOSIUM ON CLEAR AIR TURBULENCE AND ITS DETECTION, SEATTLE, WASH., AUG. 14-16, 1968, PROCEEDINGS. <A68-45259 24-20<

Language: English

Country of Origin: U.S.S.R. Country of Publication: United States

Document Type: CONFERENCE PROCEEDINGS

Documents available from AIAA Technical Library

Journal Announcement: IAA6824

Source of Abstract/Subfile: AIAA/TIS

92 (Item 92 from file: 108)

0086121 A65-16822

On the analysis of clear air turbulence by use of rawinsonde data. (Clear air turbulence in upper troposphere and lower stratosphere via rawinsonde data)

ENDLICH, R. M.; MANCUSO, R. L. /STANFORD RESEARCH INST., MENLO PARK, CALIF./.

MONTHLY WEATHER REVIEW, VOL. 93, JAN. 1965, P. 47-58. 14 REFS.

Publication Date: Jan. 1965

Contract No.: CWB-10624
Language: English
Country of Origin: United States Country of Publication: United States
Document Type: JOURNAL ARTICLE
Documents available from AIAA Technical Library
Journal Announcement: IAA6507
Source of Abstract/Subfile: AIAA/TIS

120 (Item 4 from file: 144)
02613869 PASCAL No.: 80-0440414
ATMOSPHERIC MEASUREMENTS BY VHF PULSED DOPPLER RADAR
GREEN J L; GAGE K S; VAN ZANDT T E
AERONOMY LAB.,BOULDER CO 80303,USA
Journal: I.E.E.E. TRANS. GEOSCI. ELECTRON., 1979, 17 (4) 262-280
Availability: CNRS-222H5
No. of Refs.: 3 P.
Document Type: P (SERIAL) ; A (ANALYTIC)
Country of Publication: USA
Language: ENGLISH

121 (Item 5 from file: 144)
02613865 PASCAL No.: 80-0440410
**HIGH-RESOLUTION VHF RADAR SOUNDING OF THE TROPOSPHERE AND
*STRATOSPHERE***
ROTTGER J; SCHMIDT G
MAX-PLANCK-INST. AERON.,KATLENBURG-LINDAU 3411,FEDERAL REPUBLIC OF
GERMANY
Journal: I.E.E.E. TRANS. GEOSCI. ELECTRON., 1979, 17 (4) 182-189
Availability: CNRS-222H5
No. of Refs.: 25 REF.
Document Type: P (SERIAL) ; A (ANALYTIC)
Country of Publication: USA
Language: ENGLISH

DATA

97 (Item 1 from file: 6)
1243470 NTIS Accession Number: AD-A177 498/3/XAB
**Preliminary Climatology of the Spectrum of Vertical Velocity Observed
by**

Clear-Air Doppler Radar

Ecklund, W. L. ; Gage, K. S. ; Nastrom, G. D. ; Balsley, B. B.

Colorado Univ. at Boulder. Dept. of Astrophysical Science.

Corp. Source Codes: 068646032; 415862

Sponsor: Air Force Office of Scientific Research, Bolling AFB, DC.

Report No.: AFOSR-TR-87-0262

Jul 86 9p

Languages: English Document Type: Journal article

Journal Announcement: GRAI8712

Pub. in Jnl. of Climate and Applied Meteorology, v25 n7 p885-892 Jul 86.

NTIS Prices: PC A02/MF A01

Country of Publication: United States

Contract No.: F49620-82-C-0029; 2310; A1

Multiheight time series of atmospheric vertical velocities in the troposphere and lower stratosphere observed by clear-air Doppler radar are presented at various locations around the world. Frequency spectra of vertical velocities determined from these data sets are compared with the objective of developing a preliminary climatology. We emphasize the nearly universal shape and magnitude of spectra observed during low-wind conditions. These spectra are quite flat for frequencies between the buoyancy and inertial frequencies, and they closely resemble the internal wave spectra observed in the ocean. Spectra observed under strong wind conditions, on the other hand, are greatly enhanced in magnitude, approaching the F to the minus 5/3rd power spectral slope observed for the spectrum of horizontal motions. Finally, spectra determined from both quiet and active periods at Poker Flat, Alaska, possess spectral slopes and amplitudes intermediate to those spectra determined solely from quiet or active periods at other locations. (Reprints).

101 (Item 5 from file: 6)
535316 NTIS Accession Number: AD-854 516/2
An Investigation of Stratospheric Temperature Soundings

(Master's thesis)

Botticelli, Allan P.

Air Force Inst of Tech Wright-Patterson AFB Ohio School of Engineering

Corp. Source Codes: 012225

Report No.: GSP/PH/69-1

Jun 69 144p

Document Type: Thesis

Journal Announcement: GRAI7701

Distribution limitation now removed.

NTIS Prices: PC A07/MF A01

Twenty-three rocketsonde and eleven radiosonde soundings were investigated to determine if correlation could be established between them, and to determine the propagation of temperature anomalies observed. A visual as well as a statistical study of each of these soundings was made to determine correlation. Anomaly propagation was determined by following

the movement of the centroids of these anomalies. Based on these studies, it was determined that some correlation does exist between the soundings, and it was shown that the anomalies propagate downward at a rate from 0.86 km/day near 80,000 feet to 2.19 km/day near 120,000 feet. (Author)

102 (Item 6 from file: 6)

253934 NTIS Accession Number: AD-735 419

Stratospheric Turbulence and Temperature Gradients Measured by an RB-57F.

Coldscan Flights 57 to 92

MacPherson, J. I. ; Morrissey, E. G.

National Aeronautical Establishment Ottawa (Ontario)

Corp. Source Codes: 240300

Report No.: NAE-LR-551; NRC-12318

Oct 71 86p

Journal Announcement: GRAI7205

NTIS Prices: PC A05 MF A01

Through most of the period from January 1969 to June 1971, a USAF RB-57F high altitude weather reconnaissance aircraft has carried special NRC instrumentation to measure and record stratospheric turbulence and horizontal temperature gradients encountered on routine flights at altitudes from 40,000 to 65,000 feet. The main purpose of this cooperative program, named 'Coldscan', was to collect data on atmospheric conditions at altitudes to be flown by the supersonic transports. Data are presented on the correlation between measured stratospheric turbulence and horizontal temperature gradients, on the altitude and geographical distributions of the turbulence and temperature change encounters, and on the positions of the recorded incidents relative to the jet stream. (Author)

105 (Item 9 from file: 6)

214377 NTIS Accession Number: AD-720 955

Stratospheric Turbulence and Temperature Gradients Measured by an Rb-57F.

Coldscan Flights 19 to 56

(Aeronautical rept.)

MacPherson, J. I. ; Morrissey, E. G.

National Aeronautical Establishment Ottawa (Ontario)

Corp. Source Codes: 240300

Report No.: NAE-LR-542; NRC-11774

Nov 70 81p

Journal Announcement: GRAI7110

NTIS Prices: PC A05 MF A01

Since January 1969, a USAF RB-57F high altitude weather reconnaissance aircraft has carried a special NRC instrumentation system to measure and record stratospheric turbulence and horizontal temperature gradients encountered at altitudes from 40,000 to above 60,000 feet. The chief purpose of this co-operative program, named 'Coldscan', is to collect data on atmospheric conditions at altitudes to be flown by the supersonic transports. To date, 57 data flights have been flown, covering 82,000 nautical miles of the central and western United States, Ontario, and the Pacific Ocean south of Panama. This is the second Coldscan data report and includes a summary of the results of all 57 flights, in addition to detailed accounts of a selection of 20 events from Flights 19 through 56 that showed significant temperature gradients or light to moderate

turbulence. These presentations include time histories of the recorded variables, flight tracks showing event positions, and meteorological analyses. (Author)

108 (Item 12 from file: 6)
098109 NTIS Accession Number: AD-667 222
Observations of Stratospheric Clear-Air Turbulence and Mountain Waves
over the Sierra Nevada Mountains: An Analysis of the U-2 Flights of 13-14 May, 1964

(Final rept. 14 Jun 64-14 Sep 67)

Helvey, Roger A.

California Univ Los Angeles Dept of Meteorology

Corp. Source Codes: 072271

Report No.: AFCRL-68-0001

Dec 67 93p

Journal Announcement: USGRDR6811

Report on 'Meso-Scale Calculations' project.

NTIS Prices: PC A05 MF A01

Contract No.: AF 19(628)-4146; AF-8604; 860402

Data obtained from a specially-instrumented U-2 aircraft have been used to relate clear-air turbulence with mountain wave structure, observed during two research flights in the stratosphere over the Sierra Nevada Mountains on 13 and 14 May, 1964. The several cases of severe turbulence encountered took place in regions immediately downstream of wave troughs, in area of decreased static stability and slower wind speeds associated with the prevailing upwind tilt of the waves. An expression for the Richardson number is obtained which incorporates modifications imposed upon flow through stationary disturbances such as mountain waves. (Author)

118 (Item 2 from file: 144)
05886931 PASCAL No.: 84-0388671
A brief climatology of vertical wind variability in the troposphere and *stratosphere* as seen the Poker Flat, Alaska, MST radar
NASTROM G D; GAGE K S
Control Data corp., Minneapolis MN 55440, USA
Journal: Journal of climate and applied meteorology, 1984, 23 (3)
453-460
ISSN: 0733-3021 Availability: CNRS-9644
No. of Refs.: 25 ref.
Document Type: P (Serial) ; A (Analytic)
Country of Publication: USA
Language: English

2 (Item 2 from file: 108)
1700052 A90-28703
Studies of the radar reflectivity of vertical echoes measured by the Flatland VHF clear-air Doppler radar
WARNOCK, J. M.; GAGE, K. S.; GREEN, J. L. (NOAA, Aeronomy Laboratory, Boulder, CO)
IN: Conference on Radar Meteorology, 24th, Tallahassee, FL, Mar. 27-31, 1989, Preprints (A90-28576 11-47). Boston, MA, American Meteorological

Society, 1989, p. 721-724.

Publication Date: 1989 18 Refs.

Contract No.: NSF ATM-85-12513

Language: English

Country of Origin: United States Country of Publication: United States

Document Type: CONFERENCE PAPER

Documents available from AIAA Technical Library

Journal Announcement: IAA9011

It is found that the shape of height profiles of specular echo strength measured in the troposphere and lower stratosphere by the Flatland radar agrees well with the modified Fresnel model of Gage et al. (1985) computed from high-resolution upper-air balloon data. The radar tropopause height can be determined accurately even with a radar system operating with low transmitted power. (B.J.)

Source of Abstract/Subfile: AIAA/TIS

3 (Item 3 from file: 108)

1598644 A88-49730

Observations of vertical velocities in the tropical upper troposphere and

lower stratosphere using the Arecibo 430-MHz radar

CORNISH, C. R. (Cornell University, Ithaca, NY)

Cornell Univ., Ithaca, N.Y.

Journal of Geophysical Research (ISSN 0148-0227), vol. 93, Aug. 20, 1988, p. 9419-9431.

Publication Date: Aug. 1988 39 Refs.

Contract No.: AF-AFOSR-83-0100; NSF ATM-83-10051; NSF ATM-87-06797; NAGW-362

Language: English

Country of Origin: United States Country of Publication: United States

Document Type: JOURNAL ARTICLE

Documents available from AIAA Technical Library

Journal Announcement: IAA8821

The first clear-air observations of vertical velocities in the tropical upper troposphere and lower stratosphere (8-22 km) using the Arecibo 430-MHz radar are presented. Oscillations in the vertical velocity near the Brunt-Vaisala period are observed in the lower stratosphere during the 12-hour observation period. Frequency power spectra from the vertical velocity time series show a slope between -0.5 and -1.0. Vertical wave number spectra computed from the height profiles of vertical velocities have slopes between -1.0 and -1.5. These observed slopes do not agree well with the slopes of +1/3 and -2.5 for frequency and vertical wave number spectra, respectively, predicted by a universal gravity-wave spectrum model. The spectral power of wave number spectra of a radial beam directed 15 deg off-zenith is enhanced by an order of magnitude over the spectral power levels of the vertical beam. This enhancement suggests that other geophysical processes besides gravity waves are present in the horizontal flow. The steepening of the wave number spectrum of the off-vertical beam in the lower stratosphere to near -2.0 is attributed to a quasi-inertial period wave, which was present in the horizontal flow during the observation period. (Author)

Source of Abstract/Subfile: AIAA/TIS

5 (Item 5 from file: 108)

1446752 A86-30692

Wave-turbulence interaction in the stratosphere - A case study

COT, C.; BARAT, J. (CNRS, Service d'Aeronomie, Verrieres-le-Buisson, France)

Journal of Geophysical Research (ISSN 0148-0227), vol. 91, Feb. 20, 1986, p. 2749-2756.

Publication Date: Feb. 1986 24 Refs.

Language: English

Country of Origin: France Country of Publication: United States

Document Type: JOURNAL ARTICLE

Documents available from AIAA Technical Library

Journal Announcement: IAA8613

The wave motion and turbulence field in the stratosphere are studied simultaneously using high resolution measurements of the vertical wind shear obtained from differential sounding performed between 19-24 km on July 1, 1976 in Gap-Tallard, France. The wind shear profile measured over a 150 m interval is analyzed and the wave characteristics are evaluated using Kundu's (1976) method. The data reveal that a wave of long period and of short vertical wavelength may propagate upward with a slight variation in amplitude. The turbulence field is examined and the mean dissipation rate along the 5-km sounding is calculated. The energy budget wave interaction is described and it is observed that a small portion of the wave energy is dissipated within irreversible processes. The data obtained in this experiment is applicable to the study of the spatiotemporal structure of the clear air turbulence layer. (I.F.)

Source of Abstract/Subfile: AIAA/TIS

6 (Item 6 from file: 108)

1426872 A86-18108

The diurnal variation of backscattered power from VHF Doppler radar

measurements in Colorado and Alaska

NASTROM, G. D. (Control Data Corp., Minneapolis, MN); ECKLUND, W. L.;

GAGE, K. S.; STRAUCH, R. G. (NOAA, Boulder, CO)

Radio Science (ISSN 0048-6604), vol. 20, Nov.-Dec. 1985, p. 1509-1517. USAF-supported research.

Publication Date: Dec. 1985 22 Refs.

Language: English

Country of Origin: United States Country of Publication: United States

Document Type: JOURNAL ARTICLE

Documents available from AIAA Technical Library

Journal Announcement: IAA8606

Results from a statistical analysis of backscattered signal power measurements at 4-18 km by the clear-air Doppler radars (MST radars, or wind profilers) in the Colorado Profiler Network and at Poker Flat, Alaska, show a systematic diurnal variation during the summer months. These diurnal variations have a high level of statistical significance. In the midtroposphere the diurnal range is near 7 dB with largest values in the afternoon, probably associated with the enhanced turbulence and moisture levels due to afternoon convection. In the stratosphere the diurnal range is about 5 dB over Colorado, with smallest values in the afternoon. The stratospheric cycle is interpreted as a response to modulation of the amplitude of gravity waves propagating upward from the troposphere. The diurnal cycle at all heights becomes indistinct during the winter months. (

Author)

Source of Abstract/Subfile: AIAA/TIS

7 (Item 7 from file: 108)

1426859 A86-18095

On the spectrum of atmospheric velocity fluctuations seen by MST/ST radar and their interpretation

GAGE, K. S. (NOAA, Aeronomy Laboratory, Boulder, CO); NASTROM, G. D. (Control Data Corp., Minneapolis, MN)

Radio Science (ISSN 0048-6604), vol. 20, Nov.-Dec. 1985, p. 1339-1347. NSF-USAF-supported research.

Publication Date: Dec. 1985 34 Refs.

Language: English

Country of Origin: United States Country of Publication: United States

Document Type: JOURNAL ARTICLE

Documents available from AIAA Technical Library

Journal Announcement: IAA8606

Observations of the spectrum of atmospheric motions over the range of periods from a few minutes to many hours that have been made with ST/MST radars in the past five years are considered. The spectra of both horizontal and vertical velocities are considered, and their interpretation is examined in terms of buoyancy wave theory and turbulence theory. It is found that radar and aircraft horizontal wind spectra are in reasonable accord with expectations from quasi-two-dimensional turbulence theory. The vertical velocity spectra are believed to be due to waves. Comparison of the energy levels and shapes of the horizontal and vertical velocity spectra are not consistent with existing models of internal wave spectra. However, it is possible that these inconsistencies arise from Doppler-shifting effects that are not taken into account in existing internal wave models. Nevertheless, all the observations examined support the hypothesis that quasi-two-dimensional turbulence coexists with a nearly universal spectrum of buoyancy waves. (Author)

Source of Abstract/Subfile: AIAA/TIS

8 (Item 8 from file: 108)

1405123 N85-32548

Millstone Hill radar: Capabilities for S/T observations

LORIOT, G. B.

Northeast Radio Observatory Corp., Westford, Mass. Haystack Observatory. Haystack Observatory.

In International Council of Scientific Unions Middle Atmosphere Program. Handbook for MAP. Vol. 14 p 362 (SEE N85-32466 21-46)

Publication Date: Dec. 1984

Language: English

Country of Origin: United States Country of Publication: United States

Document Type: CONFERENCE PAPER

Documents available from AIAA Technical Library

Other Availability: NTIS HC A17/MF A01; also available from SCOSTEP Secretariat, Illinois Univ., 1406 West Green Street, Urbana, Ill. 61801

Journal Announcement: STAR8521

During the past several years, the 440-MHz radar at Millstone Hill has been modified to detect coherent echoes from clear-air turbulence in the stratosphere/troposphere (S/T) over the altitude range 4-25 km. Two

distinct modes of data acquisition have been developed, and data reduction programs have been completed for one of these modes. This mode (I-mode) transmits a 10 microsec (1.5 km) pulse on the fully steerable antenna. Typically, the antenna is set at a low elevation angle (e.g., 15 deg.) to reduce the altitude resolution to approximately 1 km., and power spectra are collected at some 40 range gates. The antenna may be scanned in azimuth to obtain the total wind vector, held fixed to monitor wave motion, or scanned in elevation to monitor the horizontal extent of the turbulent activity. This steerability gives Millstone a flexible system to focus on localized events, such as lee waves or convective storms. An additional advantage at low elevations is the relatively large Doppler shift of the signal, since the LOS velocity contains a large component of the horizontal velocity. This shift separates the turbulence signal sufficiently far from the ground clutter to allow the spectral moments to be readily inferred. Some 500 hours of S/T I-mode data have been reduced to geophysical parameters, and reside on a data base at Millstone Hill. (G.L.C.)

Source of Abstract/Subfile: NASA STIF

10 (Item 10 from file: 108)

1372475 A85-26295

Vertical profile of the structural characteristics of the refractive index of light in the troposphere and stratosphere

O vertikal'nom profile strukturnoi kharakteristiki koeffitsienta prelomleniia sveta v troposfere i stratosfere

PINUS, N. Z. (Tsentral'naia Aerologicheskaiia Observatoriia, Dolgoprudny, USSR)

Akademiia Nauk SSSR, Izvestiia, Fizika Atmosfery i Okeana (ISSN 0002-3515), vol. 21, Jan. 1985, p. 90-93. In Russian.

Publication Date: Jan. 1985 13 Refs.

Language: Russian

Country of Origin: U.S.S.R. Country of Publication: U.S.S.R.

Document Type: JOURNAL ARTICLE

Documents available from AIAA Technical Library

Journal Announcement: IAA8510

Source of Abstract/Subfile: AIAA/TIS

14 (Item 14 from file: 108)

1250282 A83-36142

Poker Flat MST radar observations of shear-induced turbulence (Mesosphere-Stratosphere-Troposphere)

SMITH, S. A.; ROMICK, G. J.; JAYAWEERA, K. (Alaska, University, Fairbanks, AK)

Journal of Geophysical Research (ISSN 0148-0227), vol. 88, June 20, 1983, p. 5265-5271.

Publication Date: Jun. 1983 23 Refs.

Contract No.: AF-AFOSR-80-0286

Language: English

Country of Origin: United States Country of Publication: United States

Document Type: JOURNAL ARTICLE

Documents available from AIAA Technical Library

Journal Announcement: IAA8316

Measurements of wind speed and of the radio refractivity turbulence structure constant made with the Poker Flat (Alaska) mesosphere-stratosphere-troposphere radar are used in studying the

development of clear air turbulence (CAT) near the tropopause. Arguments and observations suggesting that the radio refractivity turbulence structure constant is proportional to the intensity of turbulence are presented. The relationship between wind shear and turbulence is investigated by using time-laged cross correlations between vertical wind shear and log structure-constant time series. From an analysis of data gathered with spatial resolutions of 2200 m and 750 m, it is found that the correlation improves as the time and spatial resolutions of the measurements improve. The implications for forecasting CAT are considered on the basis of the correlation results and a comparison of radar data with National Weather Service CAT forecasts. (C.R.)

Source of Abstract/Subfile: AIAA/TIS

15 (Item 15 from file: 108)

1230083 A83-15938

Some characteristics of clear-air turbulence in the middle stratosphere

BARAT, J. (CNRS, Service d'Aeronomie, Verrieres le Buisson, Essonne, France)

Journal of the Atmospheric Sciences, vol. 39, Nov. 1982, p. 2553-2564.

Publication Date: Nov. 1982 25 Refs.

Language: English

Country of Origin: France Country of Publication: United States

Document Type: JOURNAL ARTICLE

Documents available from AIAA Technical Library

Journal Announcement: IAA8304

Analysis of clear-air turbulence measurements obtained from highly sensitive balloon-borne instrumentation is presented. Emphasis is placed on the structure of the turbulent velocity field in the inertial range. Regions of weak turbulence are found to be associated with low Richardson numbers and negative temperature gradients. Measurements of the turbulent energy intensity are presented. The extension of the inertial range is found to be consistent with theoretical values in the case of stably stratified flow. The turbulence intensity varies significantly over a two-hour time interval. An important result is the observational evidence for a $2/3$ law behavior in the structure function at scales where the turbulent velocity field cannot be isotropic: this behavior cannot be explained by a two-dimensional turbulence field. ((Author))

17 (Item 17 from file: 108)

1223702 N83-36608

Investigation of shear-induced turbulence by MST (Mesosphere-Stratosphere

-Troposphere radar)

Final Report, 1 Oct. 1980 - 30 Sep. 1982

ROMICK, G. J.; JAYAWEEA, K.; SMITH, S. A.

Alaska Univ., Fairbanks. Geophysical Inst.

Publication Date: Sep. 1982 32P.

Report No.: AD-A129203; AFOSR-83-0437TR

Contract No.: AF-AFOSR-0286-80; AF PROJ. 2310

Language: English

Country of Origin: United States Country of Publication: United States

Document Type: REPORT

Documents available from AIAA Technical Library

Other Availability: NTIS HC A03/MF A01

Journal Announcement: STAR8324

Wind speed and $C_{\text{sub } N}^2$ measurements made with the Poker Flat, Alaska MST radar are used to study the development of clear air turbulence (CAT) near the tropopause. Arguments and observations that indicate $C_{\text{sub } N}^2$ is proportional to the intensity of turbulence are presented. The relationship between wind shear and turbulence is examined using time-lagged cross correlations of measured shears and $C_{\text{sub } N}^2$ time series. From analysis of data taken with spatial resolutions of 2200 m and 750 m, it is found that the correlation improves as the time and spatial resolutions of the measurements improve. The implications for forecasting CAT are discussed, based on the correlation results and a comparison of radar data with National Weather Service CAT forecasts. (Author (GRA))

Source of Abstract/Subfile: DTIC

20 (Item 20 from file: 108)

1127347 N81-26679

Stratospheric residence times from balloon measurements of wind shears

Final Report, 1 Jul. 1979 - 31 Dec. 1980

ROSENBERG, N.

Tel-Aviv Univ. (Israel). School of Engineering.

Place of Publication: Hanscom AFB, Mass. Publisher: Air Force Geophysics Lab.

Publication Date: Jan. 1981 18P.

Report No.: AD-A098921; AFGL-TR-81-0126

Contract No.: F49620-79-C-0180; AF PROJ. 2301

Language: English

Country of Origin: Israel Country of Publication: United States

Document Type: REPORT

Documents available from AIAA Technical Library

Other Availability: NTIS HC A02/MF A01

Journal Announcement: STAR8117

The analysis of winds measured by a corona anemometer during a 10-hour balloon flight in the stratosphere between altitudes of 17 km and 25 km has been completed. Calibration of the anemometer was accomplished by cross-correlation with a wind velocity measured from radar track of the balloon. Instrumental noise in the corona anemometer has been estimated, and its effect on calculation of wind shears is discussed. Stratospheric turbulence has been calculated from local wind shears and local temperature profiles. (Author (GRA))

Source of Abstract/Subfile: DTIC

21 (Item 21 from file: 108)

1119363 N81-18608

Climatological characteristics of high altitude wind shear and lapse rate layers

EHERNBERGER, L. J.; GUTTMAN, N. B.

National Aeronautics and Space Administration. Hugh L. Dryden Flight Research Center, Edwards, Calif.

Publication Date: Feb. 1981 99P.

Report No.: NASA-TM-81353; H-1132

Language: English

Country of Origin: United States Country of Publication: United States

Document Type: REPORT

Documents available from AIAA Technical Library

Other Availability: NTIS HC A05/MF A01

Journal Announcement: STAR8109

Indications of the climatological distribution of wind shear and temperature lapse and inversion rates as observed by rawinsonde measurements over the western United States are recorded. Frequencies of the strongest shear, lapse rates, and inversion layer strengths were observed for a 1 year period of record and were tabulated for the lower troposphere, the upper troposphere, and five altitude intervals in the lower stratosphere. Selected bivariate frequencies were also tabulated. Strong wind shears, lapse rates, and inversion are observed less frequently as altitude increases from 175 millibars to 20 millibars. On a seasonal basis the frequencies were higher in winter than in summer except for minor influences due to increased tropopause altitude in summer and the stratospheric wind reversal in the spring and fall. (S.F.)

Source of Abstract/Subfile: NASA STIF

29 (Item 29 from file: 108)

0918196 N78-17634

Stratospheric turbulence analysis

Final Report, 1 Jan. - 31 Aug. 1977

CRANE, R. K.

Environmental Research and Technology, Inc., Concord, Mass.

Publication Date: Sep. 1977 149P.

Report No.: AD-A047740; AFGL-TR-77-0207

Contract No.: F19628-77-C-0059

Language: English

Country of Origin: United States Country of Publication: United States

Document Type: REPORT

Documents available from AIAA Technical Library

Other Availability: NTIS HC A07/MF A01

Journal Announcement: STAR7808

A model was developed to combine radiosonde observations with ultrasensitive well-calibrated radar measurements of clear air turbulence to provide estimates of two eddy parameters, the eddy dissipation rate and the eddy heat diffusion coefficient. The eddy parameters were obtained as volume averages over 1 km thick layers and time averages over several hours. The model was tested using simultaneously obtained radar measurements and pilot reports of turbulence intensity from a U-2 aircraft.

The model was also shown to be consistent with other reported radar and aircraft measurements. (Author (GRA))

Source of Abstract/Subfile: DTIC

30 (Item 30 from file: 108)

0869828 A78-13111

A comparison of estimated and directly measured turbulent heat fluxes in the lower stratosphere

HECK, W. (NASA, Goddard Institute for Space Studies, New York, N.Y.)

National Aeronautics and Space Administration. Goddard Inst. for Space Studies, New York.

Monthly Weather Review, vol. 105, Oct. 1977, p. 1337-1340

Publication Date: Oct. 1977

Contract No.: NSF CD-73-00215-A01

Language: English

Country of Origin: United States Country of Publication: United States

Document Type: JOURNAL ARTICLE

Documents available from AIAA Technical Library

Journal Announcement: IAA7802

The contribution of small-scale motions to the vertical heat flux in the lower stratosphere is determined from wind and temperature fluctuation statistics obtained during the High Altitude Clear Air Turbulence investigation. Analysis of the cospectra suggests a horizontal wavelength of 3 km as the appropriate long-wave cutoff of small-scale motion. With this scale restriction, the measured vertical heat fluxes are in good agreement with the values of heat flux estimated by Lilly et al. (1974) from the kinetic energy dissipation rate. Hence, the hypothesis of Lilly et al. for estimating heat flux from the dissipation rate is considered to be reliable. It follows that, in the lower stratosphere, subsynoptic vertical transport is small compared to large-scale transport. ((Author))

43 (Item 43 from file: 108)

0684235 N74-21250

Statistical characteristics of the spectra of the wind velocity pulsations in the upper troposphere and lower stratosphere

PINUS, N. Z.

Joint Publications Research Service, Arlington, Va.

In its Meteorol. and Hydrol., No. 1, 1974 (JPRS-61729) p 116-119 (SEE N74-21239 12-20)

Publication Date: Apr. 1974

Translation Note: Transl. into ENGLISH from Meteorol. i Gidrol. (Moscow), no. 1, 1974 p 82-84

Language: English

Country of Origin: U.S.S.R. Country of Publication: United States

Document Type: JOURNAL ARTICLE; TRANSLATION

Documents available from AIAA Technical Library

Journal Announcement: STAR7412

The wind velocity pulsations spectra are presented with 50, 80, and 95% cumulative recurrence rate for the region of wave numbers of 0.00002 to 0.001/m within the layers of the atmosphere of 7-10, 10-12, 12-18, and 7-18 km. (Author)

48 (Item 48 from file: 108)

0618372 N73-15451

Some results from experimental investigations of turbulence in the troposphere and stratosphere (Statistical correlations between clear air turbulence and macrosynoptic processes in troposphere and stratosphere)

PINUS, N. Z.; SHUR, G. N.

Air Force Systems Command, Wright-Patterson AFB, Ohio. Foreign Technology Div.

Publication Date: Sep. 1972 33P.

Translation Note: Transl. into ENGLISH from Beitr. Geophysik (Leipzig), v. 79, no. 5, 1970 p 363-378

Report No.: AD-750514; FTD-HC-23-538-72

Language: English

Country of Origin: Germany, Peoples Democratic Republic of
Country of Publication: United States

Document Type: REPORT; TRANSLATION
Documents available from AIAA Technical Library
Other Availability: NTIS
Journal Announcement: STAR7306

After introductory comments on the significance of turbulence research in terms of modern aviation, the authors investigate the character of turbulence on the scales concerned here. The sources and depressions of turbulent energy as well as the forms of energy spectra are discussed here in connection with various atmospheric conditions. On the basis of aircraft observations, data is presented on the appearance and character of turbulence in the stratosphere and on the level of the tropopause. Finally, the results are given for a statistical investigation of the tie-in between turbulence and macrosynoptic processes, from which a synoptic-statistical method for the prediction of clear-air turbulence is derived. (Author (GRA))

) Source of Abstract/Subfile: DTIC

51 (Item 51 from file: 108)
0593259 A73-25785

Mountain waves and CAT encountered by the XB-70 in the stratosphere.
SCOGGINS, J. R. (Texas A & M University, College Station, Tex.);
INCROCCI, T. P. (USAF, Washington, D.C.; Global Weather Central, Omaha, Neb.)

Journal of Aircraft, vol. 10, Mar. 1973, p. 172-180.

Publication Date: Mar. 1973 20 Refs.

Contract No.: NGR-44-001-081

Language: English

Country of Origin: United States Country of Publication: United States

Document Type: JOURNAL ARTICLE

Documents available from AIAA Technical Library

Journal Announcement: IAA7311

The data from 36 XB-70 flights conducted over the mountainous regions of the western United States together with rawinsonde data were used to investigate relationships between conditions favorable for mountain waves and clear air turbulence. Profiles for the Scorer parameter and the gradient Richardson number were evaluated from the rawinsonde data. The Scorer parameter and the gradient Richardson number profiles were computed on those days when the XB-70 flew, and these results compared to model profiles and related to the reported turbulence. Ascent rate profiles of rawinsonde balloons were analyzed from which the presence of mountain or lee waves was inferred. ((Author))

52 (Item 52 from file: 108)
0571884 N72-28304

Fine structure of the middle and high stratosphere. Detection of clear air turbulence. Application to flights envisaged from supersonic transport aircraft (Wind, temperature, and clear air turbulence in middle and upper stratosphere)

BARBE, G. D.; et al.

National Lending Library for Science and Technology, Boston Spa (England).

Publication Date: 1972 19P.

Translation Note: Transl. into ENGLISH from the publ. "'French/American Meteorological Societies Joint Meeting" Paris, 1971

Report No.: NLL-M-22438-(5828.4F)
Language: English
Country of Origin: France Country of Publication: United Kingdom
Document Type: CONFERENCE PAPER; TRANSLATION
Documents available from AIAA Technical Library
Other Availability: Natl. Lending Library, Boston Spa, Engl.: 2 NLL
photocopy coupons
Journal Announcement: STAR7219
Wind and fine scale temperature soundings were carried out under a variety of experimental conditions. Clear air turbulence measurements observations were made using Canberra and Concorde aircraft. The results are presented in the form of curves giving the distributions as a function of altitude, height, wind speed, and temperature. (K.P.D.)
Source of Abstract/Subfile: NASA STIF

54 (Item 54 from file: 108)
0563591 N72-19682
CAT investigations in the stratosphere (Observations of clear air turbulence in stratosphere by high altitude subsonic aircraft)
VINNICHENKO, N. K.; PINUS, N. Z.; SUR, G. N.
National Lending Library for Science and Technology, Boston Spa (England).
Publication Date: 1971 11P.
Translation Note: Transl. into ENGLISH from Tr. Tsentr. Aerolog. Observ. (Moscow), v. 100, 1970 p 86-98

Report No.: NLL-M-22069-(5828.4F)
Language: English
Country of Origin: U.S.S.R. Country of Publication: United Kingdom
Document Type: JOURNAL ARTICLE; TRANSLATION
Documents available from AIAA Technical Library
Other Availability: Natl. Lending Library, Boston Spa, Engl.: 1 NLL
photocopy coupon
Journal Announcement: STAR7210
Results of experimental studies of turbulence in the stratosphere on a specially equipped high altitude subsonic aircraft flying over mountains and plains are considered. Data on the geometry and structure of zones of turbulence are obtained. In the stratosphere, as in the troposphere, there are local zones of turbulence, but the extent and depth of these zones are much less in the stratosphere. Zones of turbulence in the stratosphere are considerably more intense over mountains than over plains, because the stratosphere is made turbulent by breaking mountain waves. Examples of the distribution of zones of turbulence with respect to the tropopause and the level of maximum wind are given. Correlation and spectral characteristics of CAT in the stratosphere are also given. Some correlation functions have a harmonic tail which is not damped; this suggests that there are wave motions in the stratosphere. Power spectra of the horizontal wind component in the stratosphere, covering the meso-scale and micro-scale regions, are also given. (Author)

55 (Item 55 from file: 108)
0537176 A72-28867
Meteorological parameters versus CAT encountered in the stratosphere by the XB-70 airplane. (Synoptic meteorological parameters vs CAT encountered

in stratosphere by XB-70 airplane, presenting frequency distributions and probability tables)

SCOGGINS, J. R. (Texas A & M University, College Station, Tex.)

In: International Conference on Aerospace and Aeronautical Meteorology, 1st, Washington, D.C., May 22-26, 1972, Preprints. (A72-28801 13-20) Boston, American Meteorological Society, 1972, p. 361-366.

Publication Date: 1972 18 Refs.

Contract No.: NGR-44-001-081

Language: English

Country of Origin: United States Country of Publication: United States

Document Type: CONFERENCE PAPER

Journal Announcement: IAA7213

Frequency distributions prepared from synoptic meteorological parameters associated with turbulent and nonturbulent conditions encountered by the XB-70 aircraft at altitudes generally between 12 and 20 km in the stratosphere show that turbulence is associated with certain ranges or critical values of the parameters. Certain combinations of the variables are associated with turbulence for at least one-fourth to one-third of the observations. (G.R.)

Source of Abstract/Subfile: AIAA/TIS

56 (Item 56 from file: 108)

0530747 A72-22438

Temperature gradients in stratospheric turbulence. (Horizontal temperature variations relation to stratospheric CAT based on U-2 flight data)

WACO, D. E. (Lockheed-California Co., Burbank, Calif.)

Journal of Applied Meteorology, vol. 11, Feb. 1972, p. 99-107.

Publication Date: Feb. 1972 25 Refs.

Language: English

Country of Origin: United States Country of Publication: United States

Document Type: JOURNAL ARTICLE

Documents available from AIAA Technical Library

Journal Announcement: IAA7209

Use of data obtained from U-2 HICAT flights to relate the magnitudes of horizontal temperature changes to flight conditions. The empirical findings can be used in estimating the effectiveness of aircraft-borne sensors which rely on temperature measurements for the remote detection of clear air turbulence. Gust velocity changes of at least 20 ft/sec occurred in all but one of 68 turbulence encounters in which temperature changes were 3 C or higher, and in only 13 of 97 cases with changes of less than 1C. Although short-period temperature variations were generally small during smooth flight and increased in magnitude during rougher flight, exceptions were noted. Large horizontal temperature changes were observed during smooth flight in the vicinity of severe turbulence and during occasional flights where the temperature changed appreciably over shallow vertical layers. Small changes were sometimes noted during moderate turbulence when the vertical temperature structure was nearly isothermal. ((Author))

57 (Item 57 from file: 108)

0522985 A72-14676

Fine structure of the medium and upper stratosphere: Detection of clear

air turbulence - Application to flights anticipated for supersonic

transport aircraft (Stratospheric circulation and air temperature horizontal and vertical distribution, discussing CAT at supersonic transport heights)

Structure fine de la stratosphere moyenne et elevee: Detection de la turbulence en ciel clair - Application aux vols envisages pour les avions de transport supersoniques

BARBE, G. D. (Etablissement d'Etudes et de Recherches de la Meteorologie Nationale, Paris, France)

Societe Meteorologique Francaise and American Meteorological Society, Colloque sur la Meteorologie Aeronautique, Paris and Orly, France, May 24-26, 1971, Paper. 37 p. In French.

Publication Date: May 1971 14 Refs.

Language: French

Country of Origin: France Country of Publication: France

Document Type: CONFERENCE PAPER

Documents available from AIAA Technical Library

Journal Announcement: IAA7204

Discussion of the vertical and horizontal distribution of the circulation and air temperature of the stratosphere, which in certain cases is very turbulent, more so, it appears, than the troposphere. Clear air turbulence (CAT) can be encountered at altitudes several km above the levels flown by present-day transports. Temperature variations amounting to several degrees have been measured within air layers about 100 m thick and 10 km long. In certain cases, this temperature variation affects thicker layers. A certain correlation appears to exist between CAT and the 'irregularities' measured either in a vertical or horizontal plane involving temperature and the horizontal wind vector. (F.R.L.)

Source of Abstract/Subfile: AIAA/TIS

58 (Item 58 from file: 108)

0519591 A72-11282

An analysis of conditions associated with an occurrence of stratospheric CAT. (Stratospheric CAT relationships to baroclinic zones and Richardson number examined from aircraft observed cross sections data)

DELAY, R. D. (USAF, Air Weather Service); DUTTON, J. A. (Pennsylvania State University, University Park, Pa.)

Journal of the Atmospheric Sciences, vol. 28, Oct. 1971, p. 1272-1279.

Publication Date: Oct. 1971 10 Refs.

Contract No.: NSF 1595X

Language: English

Country of Origin: United States Country of Publication: United States

Document Type: JOURNAL ARTICLE

Documents available from AIAA Technical Library

Journal Announcement: IAA7201

Cross sections of potential temperature, wind shear, and gradient Richardson number were constructed from data obtained during a Project HICAT flight and analyzed to determine the relationship to clear air turbulence in the stratosphere. CAT was found to be associated with strong baroclinic zones and with a critical value of the Richardson number of 0.25. Energy budgets for five patches of turbulence associated with this outbreak of stratospheric clear air turbulence were also examined, and found to balance within 4-18% of the total rate of shear production. (Author))

60 (Item 60 from file: 108)
0513267 N71-33671

Clear air turbulence in the Australian stratosphere (Meteorological flight search for clear air turbulence in stratosphere above Australia, 1966)

RIDER, C. K.; THOMSON, M. R.

Department of Supply, Melbourne (Australia). AERONAUTICAL RESEARCH LABS.

Publication Date: Jan. 1971 14P.

Publication Note: ITS STRUCT. AND MATER. NOTE 362

Language: English

Country of Origin: Australia Country of Publication: Australia

Document Type: REPORT

Documents available from AIAA Technical Library

Other Availability: NTIS AVAIL- NTIS

Journal Announcement: STAR7120

64 (Item 64 from file: 108)
0474177 A71-29755

Measurements of stratospheric airflow and clear air turbulence, up to

63000 ft, over and downwind of mountainous terrain (Stratospheric air flow patterns and CAT measurements onboard aircraft over and downwind of Western U.S. mountain terrain)

NICHOLLS, J. M. /METEOROLOGICAL OFFICE, LONDON, ENGLAND/.

Place of Publication: LONDON Publisher: ROYAL AERONAUTICAL SOCIETY

Publication Date: 1971 12P.

Publication Note: CONFERENCE CO-SPONSORED BY THE AMERICAN INST. OF AERONAUTICS AND ASTRONAUTICS AND THE CANADIAN AERONAUTICS AND SPACE INST.

Presentation Note: IN- ROYAL AERONAUTICAL SOCIETY, INTERNATIONAL CONFERENCE ON ATMOSPHERIC TURBULENCE, LONDON, ENGLAND, MAY 18-21, 1971,

PROCEEDINGS. /A71-29749 14-20/

Language: English

Country of Origin: United Kingdom Country of Publication: United Kingdom

Document Type: CONFERENCE PAPER

Documents available from AIAA Technical Library

Journal Announcement: IAA7114

Source of Abstract/Subfile: AIAA/TIS

66 (Item 66 from file: 108)
0454989 A71-10567

Measurement of clear air turbulence in the lower stratosphere using the

Millstone Hill L-band radar (Thin CAT layer detection in lower stratosphere by L band radar complemented by radiosonde and U-2 aircraft probes)

CRANE, R. K. /MIT, LEXINGTON, MASS./.

Place of Publication: BOSTON Publisher: AMERICAN METEOROLOGICAL SOCIETY

Publication Date: 1970 6P.

Publication Note: USAF-SPONSORED RESEARCH.

Presentation Note: IN- AMERICAN METEOROLOGICAL SOCIETY, RADAR METEOROLOGY CONFERENCE, 14TH, TUCSON, ARIZ., NOV. 17-20, 1970, PROCEEDINGS. P. 101-106. /A71-10551 01-20/

Language: English
Country of Origin: United States Country of Publication: United States
Document Type: CONFERENCE PAPER
Documents available from AIAA Technical Library
Journal Announcement: IAA7101
Source of Abstract/Subfile: AIAA/TIS

71 (Item 71 from file: 108)
0405660 A70-30124
An observation of gravity waves in shear flow in the lower stratosphere
(Lower stratosphere temperature and wind periodic variations associated
with shear flow gravity waves)
AXFORD, D. N./METEOROLOGICAL OFFICE, BRACKNELL, BERKS., ENGLAND/.
ROYAL METEOROLOGICAL SOCIETY, QUARTERLY JOURNAL, VOL. 96, P. 273-286.
Publication Date: Apr. 1970 8 Refs.
Language: English
Country of Origin: United Kingdom Country of Publication: United
Kingdom
Document Type: JOURNAL ARTICLE
Documents available from AIAA Technical Library
Journal Announcement: IAA7014
Source of Abstract/Subfile: AIAA/TIS

72 (Item 72 from file: 108)
0403631 A70-28095
Vertical extent of turbulence in clear air above the tops of
thunderstorms (Stratospheric clear air turbulence /CAT/ vertical extent
above thunderstorm graphically represented)
PROPHET, D. T./LOCKHEED-CALIFORNIA CO., BURBANK, CALIF./.
JOURNAL OF APPLIED METEOROLOGY, VOL. 9, P. 320, 321.
Publication Date: Apr. 1970
Language: English
Country of Publication: United States
Document Type: JOURNAL ARTICLE
Documents available from AIAA Technical Library
Journal Announcement: IAA7012
Source of Abstract/Subfile: AIAA/TIS

76 (Item 76 from file: 108)
0384283 N69-40091
Atmospheric temperature changes associated with high altitude
turbulence
(Test flight data analyzed for atmospheric temperature changes associated
with high altitude turbulence)
KADLEC, P. W.
Eastern Air Lines, Inc., Miami, Fla.
Publication Date: Jul. 1969 27P.
Report No.: NASA-CR-106204
Contract No.: NAS4-1392
Language: English
Country of Origin: United States Country of Publication: United States
Document Type: REPORT
Documents available from AIAA Technical Library
Other Availability: NTIS

Journal Announcement: STAR6924

81 (Item 81 from file: 108)
0344818 A69-33732
Clear Air Turbulence and its Detection, Boeing Company, Symposium,
Seattle, Wash., August 14-16, 1968, Proceedings. (Clear air turbulence and detection - Conference, Seattle, August 1968)
GOLDBURG, A.; PAO, H.-H.
Place of Publication: NEW YORK Publisher: PLENUM PRESS
Publication Date: 1969 555P.
Presentation Note: CLEAR AIR TURBULENCE AND ITS DETECTION, BOEING CO., SYMPOSIUM, SEATTLE, WASH., AUG. 14- 16, 1968, PROCEEDINGS.
Language: English
Country of Origin: United States Country of Publication: United States
Document Type: CONFERENCE PROCEEDINGS
Documents available from AIAA Technical Library
Journal Announcement: IAA6917
Source of Abstract/Subfile: AIAA/TIS

85 (Item 85 from file: 108)
0307017 N68-23996
Observations of stratospheric clear-air turbulence and mountain waves
over the Sierra Nevada Mountains - An analysis of the U-2 flights of 13-14 May, 1964 Final report, 14 Jun. 1964 - 14 Sep. 1966 (Wave structure relation to clear air turbulence observed in U-2 aircraft over Sierra Nevadas)
HELVEY, R. A.
California Univ., Los Angeles. DEPT. OF METEOROLOGY.
Publication Date: Dec. 1967 93P.
Report No.: AFCRL-68-0001; AD-667222
Contract No.: AF 19/628/-4146
Language: English
Country of Origin: United States Country of Publication: United States
Document Type: REPORT
Documents available from AIAA Technical Library
Journal Announcement: STAR6813

86 (Item 86 from file: 108)
0292370 A68-45280
Recent investigations of clear air turbulence in the USSR. (Clear air turbulence research in U.S.S.R., discussing energy spectra measurements and effects on aircraft at various heights in troposphere and stratosphere)
VINNICHENKO, N. K. /TSENTRAL'NAIA AEROLOGICHESKAIA OBSERVATORIIA, DOLGO-PRUDNAYA, USSR/.
Place of Publication: SEATTLE, WASH. Publisher: BOEING SCIENTIFIC RESEARCH LABS.
Publication Date: 1968 6P.
Presentation Note: IN- BOEING SCIENTIFIC RESEARCH LABS., SYMPOSIUM ON CLEAR AIR TURBULENCE AND ITS DETECTION, SEATTLE, WASH., AUG. 14-16, 1968, PROCEEDINGS. <A68-45259 24-20<
Language: English
Country of Origin: U.S.S.R. Country of Publication: United States

Document Type: CONFERENCE PROCEEDINGS
Documents available from AIAA Technical Library
Journal Announcement: IAA6824
Source of Abstract/Subfile: AIAA/TIS

87 (Item 87 from file: 108)
0281595 A68-34505

Case studies of the distribution of cat in the troposphere and stratosphere. (Clear air turbulence in stratosphere over Rocky Mountains and upper troposphere over midwestern plains)

DUTTON, J. A. /PENNSYLVANIA STATE U., UNIVERSITY PARK, PA./; HEMMERICH, K. H. /ESSA, WASHINGTON, D.C./; LOVING, N. V. /USAF, SYSTEMS COMMAND, RESEARCH AND TECHNOLOGY DIV., DAYTON, OHIO./; MCCREARY, G. /USAF, WASHINGTON, D.C./; PANOFSKY, H. A.

JOURNAL OF APPLIED METEOROLOGY, VOL. 7, P. 384-389.

Publication Date: Jun. 1968 9 Refs.

Language: English

Country of Origin: United States Country of Publication: United States

Document Type: JOURNAL ARTICLE

Documents available from AIAA Technical Library

Journal Announcement: IAA6817

Source of Abstract/Subfile: AIAA/TIS

88 (Item 88 from file: 108)
0252056 N67-35480

Mesoscale structure of the atmosphere in regions of clear-air turbulence,

volume I (Mesoscale structure of atmosphere in regions of clear air turbulence determined by aircraft observations of wind, temperature, and ozone in upper troposphere and lower stratosphere)

PENN, S.; PISINSKI, T. A.

Air Force Cambridge Research Labs., Hanscom AFB, Mass. METEOROLOGY LAB.

APR. 1967 96 P REFS ITS SURU. IN GEOPHYS. NO. 190

Publication Date: Apr. 1967

Report No.: AFCRL-67-0115; AD-654267

Language: English

Country of Origin: United States Country of Publication: United States

Document Type: REPORT

Documents available from AIAA Technical Library

Journal Announcement: STAR6721

89 (Item 89 from file: 108)
0244817 N67-28136

Some data on turbulence in the upper troposphere and stratosphere causing

airplane buffeting (Aircraft buffeting due to clear air turbulence in upper troposphere and stratosphere)

PINUS, N. Z.; SHUR, G. N.; VINNICHENKO, N. K.

Joint Publications Research Service, Washington, D. C.

IN ITS METEOROL. AND HYDROL., NO. 11, 1966 21 FEB. 1967 P 35-47 REFS

PRESENTED AT THE SCI. CONF. ON THE FORECASTING OF WIND, TEMP. AND TURBULENCE FOR JET AIRPLANES, MOSCOW, 10-13 NOV. 1965 /SEE N67-28133 15-20/

Publication Date: Feb. 1967

Language: English
Country of Origin: U.S.S.R. Country of Publication: United States
Document Type: REPORT
Journal Announcement: STAR6715
Source of Abstract/Subfile: NASA STIF

120 (Item 4 from file: 144)
02613869 PASCAL No.: 80-0440414
ATMOSPHERIC MEASUREMENTS BY VHF PULSED DOPPLER RADAR
GREEN J L; GAGE K S; VAN ZANDT T E
AERONOMY LAB., BOULDER CO 80303, USA
Journal: I.E.E.E. TRANS. GEOSCI. ELECTRON., 1979, 17 (4) 262-280
Availability: CNRS-222H5
No. of Refs.: 3 P.
Document Type: P (SERIAL) ; A (ANALYTIC)
Country of Publication: USA
Language: ENGLISH

121 (Item 5 from file: 144)
02613865 PASCAL No.: 80-0440410
**HIGH-RESOLUTION VHF RADAR SOUNDING OF THE TROPOSPHERE AND
*STRATOSPHERE***
ROTTGER J; SCHMIDT G
MAX-PLANCK-INST. AERON., KATLENBURG-LINDAU 3411, FEDERAL REPUBLIC OF
GERMANY
Journal: I.E.E.E. TRANS. GEOSCI. ELECTRON., 1979, 17 (4) 182-189
Availability: CNRS-222H5
No. of Refs.: 25 REF.
Document Type: P (SERIAL) ; A (ANALYTIC)
Country of Publication: USA
Language: ENGLISH

REMOTE PROBING

97 (Item 1 from file: 6)
1243470 NTIS Accession Number: AD-A177 498/3/XAB
Preliminary Climatology of the Spectrum of Vertical Velocity Observed by Clear-Air Doppler Radar
Ecklund, W. L. ; Gage, K. S. ; Nastrom, G. D. ; Balsley, B. B.
Colorado Univ. at Boulder. Dept. of Astrophysical Science.
Corp. Source Codes: 068646032; 415862
Sponsor: Air Force Office of Scientific Research, Bolling AFB, DC.
Report No.: AFOSR-TR-87-0262
Jul 86 9p
Languages: English Document Type: Journal article
Journal Announcement: GRAI8712
Pub. in Jnl. of Climate and Applied Meteorology, v25 n7 p885-892
Jul 86.
NTIS Prices: PC A02/MF A01
Country of Publication: United States
Contract No.: F49620-82-C-0029; 2310; A1
Multiheight time series of atmospheric vertical velocities in the troposphere and lower stratosphere observed by clear-air Doppler radar are presented at various locations around the world. Frequency spectra of vertical velocities determined from these data sets are compared with the objective of developing a preliminary climatology. We emphasize the nearly universal shape and magnitude of spectra observed during low-wind conditions. These spectra are quite flat for frequencies between the buoyancy and inertial frequencies, and they closely resemble the internal wave spectra observed in the ocean. Spectra observed under strong wind conditions, on the other hand, are greatly enhanced in magnitude, approaching the F to the minus 5/3rd power spectral slope observed for the spectrum of horizontal motions. Finally, spectra determined from both quiet and active periods at Poker Flat, Alaska, possess spectral slopes and amplitudes intermediate to those spectra determined solely from quiet or active periods at other locations. (Reprints).

109 (Item 1 from file: 2)
02384865 INSPEC Abstract Number: A85023903
Title: Simultaneous measurements of temperature and velocity fluctuations within *clear* *air* *turbulence* layers: analysis of the estimate of

dissipation rate by remote sensing techniques

Author(s): Barat, J.; Bertin, F.

Author Affiliation: Paris VI Univ., France

Journal: Journal of the Atmospheric Sciences vol.41, no.9
p.1613-19

Publication Date: 1 May 1984 Country of Publication: USA

CODEN: JAHSAK ISSN: 0022-4928

Language: English Document Type: Journal Paper (JP)

Treatment: Experimental (X)

Abstract: Estimates of dissipation rate from remote-sensing techniques

measuring the structure parameter C_{n^2} of density turbulent

fluctuations assume a relationship between C_{n^2} and the

dissipation rate ϵ . In order to obtain a precise test of this relation, in situ observations are of major importance. The authors present

in this paper the first simultaneous in situ measurements of these

parameters. The analysis of data shows that the models of turbulence used

in the radar literature are not always fully justified and that the estimate of dissipation rate may be underestimated. (23 Refs)

115 (Item 7 from file: 2)

00316079 INSPEC Abstract Number: A71074317

Title: An analysis of heat-, momentum-transport, and spectra for *clear*

air* *turbulence* in mid-*stratosphere

Author(s): Kao, S.-K.; Gebhard, J.B.

Author Affiliation: Univ. Utah, Salt Lake City, UT, USA

Journal: Pure and Applied Geophysics vol.87, no.5 p.180-5

Publication Date: 1971 Country of Publication: Switzerland

CODEN: PAGYAV ISSN: 0033-4553

Language: English Document Type: Journal Paper (JP)

Treatment: Theoretical (T)

Abstract: An analysis of the clear air turbulence in the mid-stratosphere

indicates that the turbulence is characterized by an anisotropic field of

turbulence with an intense lateral component of the turbulence, associated

with strong thermally stable stratification. The Richardson number in the

region of turbulence is generally smaller than $1/4$, the

Taylor's criterion for a stratified shear flow. The cospectra for the momentum transport by the streamwise, lateral, and vertical components of

the velocity show similarity in their distribution, decreasing with

increasing wavenumber. The cospectra for the heat transport by the

streamwise, lateral, and vertical components of the velocity show similarity in their distribution, decreasing with increasing wavenumber. The cospectra for the heat transport by the streamwise, lateral and vertical components of the velocity show similarity in the high and medium wavenumber ranges, but not in the low wavenumber range of the spectra. The power spectra of the temperature and wind speed are very similar, and are approximately proportional to the $^{-5/3}$ power of the wavenumber. The power spectra of the streamwise and lateral components of the velocity are approximately proportional to the $^{-2}$ power of the wavenumber, whereas the spectrum of the vertical component of the velocity is approximately proportional to the $^{-1}$ power of the wavenumber. (12 Refs)

118 (Item 2 from file: 144)

05886931 PASCAL No.: 84-0388671

A brief climatology of vertical wind variability in the troposphere and

stratosphere as seen the Poker Flat, Alaska, MST radar

NASTROM GD; GAGE KS

Control Data corp., Minneapolis MN 55440, USA

Journal: Journal of climate and applied meteorology, 1984, 23 (3)
453-460

ISSN: 0733-3021 Availability: CNRS-9644

No. of Refs.: 25 ref.

Document Type: P (Serial) ; A (Analytic)

Country of Publication: USA

Language: English

123 (Item 1 from file: 434)

11102474 Genuine Article#: GG358 Number of References: 40

Title: A STOCHASTIC-MODEL OF GRAVITY-WAVE INDUCED

CLEAR*-*AIR

TURBULENCE

Author(s): FAIRALL CW; WHITE AB; THOMSON DW

Corporate Source: NOAA, ERL ATMOSPHERIC STUDIES PROGRAM
AREA, 325

BROADWAY/BOULDER//CO/80303; PENN STATE UNIV, DEPT
METEOROL/UNIVERSITY

PK//PA/16802

Journal: JOURNAL OF THE ATMOSPHERIC SCIENCES, 1991, V48, N15,
P1771-1790

Language: ENGLISH Document Type: ARTICLE

Abstract: We examine the consequences of using a vertical wavenumber spectral model to describe variations of vertical profiles of

atmospheric variables (horizontal and vertical wind, temperature, and other scalars) about a mean profile. At high wavenumbers the model exhibits a wavenumber to the -3 dependence, which is characteristic of a continuum of internal gravity waves whose amplitudes are controlled by a breaking process.

By employing a random phase between wavenumber amplitude components, a reverse fourier transform of the spectrum yields simulated profiles of velocity and thermal variability as well as shear and Brunt-Vaisala frequency variability. Individual components of the vertical shear of the horizontal wind and the Brunt-Vaisala frequency exhibit Gaussian distributions; the square of the magnitude of the shear exhibits a Rice-Nakagami distribution. Assuming regions with $Ri < 0.25$ are turbulent, we can examine a number of aspects of the occurrence of clear-air turbulent breakdown in the stratified free atmosphere. For a typical tropospheric condition, the average turbulent layer thickness turns out to be about 35 m and about 20% of the troposphere appears to be actively turbulent. The majority of the turbulent layers appear to be due to autoconvective overturning instead of Kelvin-Helmholtz dynamic instability. Computations of profiles of the refractive index structure function parameter, $C(n)^2$, and the rate of dissipation of turbulent kinetic energy, epsilon, are found to be quite sensitive to the assumptions of the relationship of turbulent length scale to layer thickness, the growth of turbulent layers after breakdown, and the threshold sensitivity and sampling strategy of measurement systems (e.g., clear-air radar).

6 (Item 6 from file: 108)
1426872 A86-18108

The diurnal variation of backscattered power from VHF Doppler radar

measurements in Colorado and Alaska

NASTROM, G. D. (Control Data Corp., Minneapolis, MN); ECKLUND, W. L.;

GAGE, K. S.; STRAUCH, R. G. (NOAA, Boulder, CO)

Radio Science (ISSN 0048-6604), vol. 20, Nov.-Dec. 1985, p. 1509-1517.

USAF-supported research.

Publication Date: Dec. 1985 22 Refs.

Language: English

Country of Origin: United States Country of Publication: United States

Document Type: JOURNAL ARTICLE

Documents available from AIAA Technical Library

Journal Announcement: IAA8606

Results from a statistical analysis of backscattered signal power measurements at 4-18 km by the clear-air Doppler radars (MST radars, or wind profilers) in the Colorado Profiler Network and at Poker Flat, Alaska, show a systematic diurnal variation during the summer months. These diurnal variations have a high level of statistical significance. In the midtroposphere the diurnal range is near 7 dB with largest values in the afternoon, probably associated with the enhanced turbulence and moisture levels due to afternoon convection. In the stratosphere the diurnal range is about 5 dB over Colorado, with smallest values in the afternoon. The stratospheric cycle is interpreted as a response to modulation of the amplitude of gravity waves propagating upward from the troposphere. The diurnal cycle at all heights becomes indistinct during the winter months. (

Author)

Source of Abstract/Subfile: AIAA/TIS

7 (Item 7 from file: 108)

1426859 A86-18095

On the spectrum of atmospheric velocity fluctuations seen by MST/ST radar
and their interpretation

GAGE, K. S. (NOAA, Aeronomy Laboratory, Boulder, CO);
NASTROM, G. D.

(Control Data Corp., Minneapolis, MN)

Radio Science (ISSN 0048-6604), vol. 20, Nov.-Dec. 1985, p. 1339-1347.

NSF-USAF-supported research.

Publication Date: Dec. 1985 34 Refs.

Language: English

Country of Origin: United States Country of Publication: United States

Document Type: JOURNAL ARTICLE

Documents available from AIAA Technical Library

Journal Announcement: IAA8606

Observations of the spectrum of atmospheric motions over the range of periods from a few minutes to many hours that have been made with ST/MST radars in the past five years are considered. The spectra of both

horizontal and vertical velocities are considered, and their interpretation is examined in terms of buoyancy wave theory and turbulence theory. It is found that radar and aircraft horizontal wind spectra are in reasonable accord with expectations from quasi-two-dimensional turbulence theory. The vertical velocity spectra are believed to be due to waves. Comparison of the energy levels and shapes of the horizontal and vertical velocity spectra are not consistent with existing models of internal wave spectra. However, it is possible that these inconsistencies arise from Doppler-shifting effects that are not taken into account in existing internal wave models. Nevertheless, all the observations examined support the hypothesis that quasi-two-dimensional turbulence coexists with a nearly universal spectrum of buoyancy waves. (Author)
Source of Abstract/Subfile: AIAA/TIS

9 (Item 9 from file: 108)
1377035 A85-28701

Observations of vertical motions in the troposphere and lower

stratosphere using three closely-spaced ST radars

BALSLEY, B. B.; ECKLUND, W. L.; CARTER, D. A. (NOAA, Aeronomy Laboratory, Boulder, CO); CROCHET, M. (Laboratoire de Sondages Electromagnetiques de l'Environnement, Toulon, France; NOAA, Aeronomy Laboratory, Boulder, CO); RIDDLE, A. C.; GARELLO, R. (Colorado, University; NOAA, Aeronomy Laboratory, Boulder, CO)

IN: Conference on Radar Meteorology, 21st, Edmonton, Alberta, Canada,

September 19-23, 1983, Preprints (A85-28676 12-47).

Boston, MA, American

Meteorological Society, 1983, p. 148-152. Research supported by the Centre

National de la Recherche Scientifique, Institut National d'Astronomie et de

Geophysique and NSF.

Publication Date: 1983 5 Refs.

Language: English

Country of Origin: United States Country of Publication: United States

Document Type: CONFERENCE PAPER

Documents available from AIAA Technical Library

Journal Announcement: IAA8512

Continuous observations of vertical winds, performed during the Alpine

Experiment by a network of three stratosphere-troposphere radars, are discussed. The vertical velocity spectra were acquired between 3 and 20 km of altitude at 750-m intervals with time resolution of 1 min, covering quiet and active-wind periods extending from 2 to 200 minutes. It was established that the winds measured by the vertically directed beams are truly vertical; the increased slope of the vertical spectra, observed during high wind activity, suggests, however, that the antennas are registering a component of the horizontal flow. Finally, the increased coherence between sites at periods longer than about 30 min indicates that a considerable organized wave activity is present at longer periods. (L.T.)

Source of Abstract/Subfile: AIAA/TIS

12 (Item 12 from file: 108)
1351064 A76-39522

The role of turbulent heat flux in the generation of potential vorticity

in the vicinity of upper-level jet stream systems

SHAPIRO, M. A. (National Center for Atmospheric Research, Boulder, Colo.)

Monthly Weather Review, vol. 104, July 1976, p. 892-906.

Publication Date: Jul. 1976 28 Refs.

Language: English

Country of Origin: United States Country of Publication: United States

Document Type: JOURNAL ARTICLE

Documents available from AIAA Technical Library

Journal Announcement: IAA7619

Results from three case-study investigations of upper-level jet-stream systems document the existence of stratospheric mesoscale cyclonic wind

shear in the layer of maximum wind. Anomalously high values of potential vorticity are shown to coincide with the mesoscale cyclonic shear-zone. The

high values of potential vorticity within an upper-level frontal zone were shown to result from shearing vorticity in the mesoscale high-potential-vorticity region of the stratosphere, which is transported downward into the tropospheric frontal zone and becomes transformed into curvature vorticity with little change in thermal stability. The vertical gradient of diabatic temperature change resulting from vertical

shear-induced turbulent heat flux in layers of clear air turbulence is proposed as the generation mechanism responsible for large values of potential vorticity on the mesoscale. It is proposed that turbulent-scale mixing processes are of first-order importance in the evolution of jet-stream frontal-zone systems. ((Author))

14 (Item 14 from file: 108)
1250282 A83-36142
Poker Flat MST radar observations of shear-induced turbulence (

Mesosphere-Stratosphere-Troposphere)

SMITH, S. A.; ROMICK, G. J.; JAYAWEERA, K. (Alaska, University, Fairbanks, AK)

Journal of Geophysical Research (ISSN 0148-0227), vol. 88, June 20, 1983, p. 5265-5271.

Publication Date: Jun. 1983 23 Refs.

Contract No.: AF-AFOSR-80-0286

Language: English

Country of Origin: United States Country of Publication: United States

Document Type: JOURNAL ARTICLE

Documents available from AIAA Technical Library

Journal Announcement: IAA8316

Measurements of wind speed and of the radio refractivity turbulence

structure constant made with the Poker Flat (Alaska) mesosphere-stratosphere-troposphere radar are used in studying the development of clear air turbulence (CAT) near the tropopause.

Arguments

and observations suggesting that the radio refractivity turbulence

structure constant is proportional to the intensity of turbulence are

presented. The relationship between wind shear and turbulence is

investigated by using time-laged cross correlations between vertical wind

shear and log structure-constant time series. From an analysis of data

gathered with spatial resolutions of 2200 m and 750 m, it is found that the

correlation improves as the time and spatial resolutions of the measurements improve. The implications for forecasting CAT are considered

on the basis of the correlation results and a comparison of radar data with

National Weather Service CAT forecasts. (C.R.)

Source of Abstract/Subfile: AIAA/TIS

15 (Item 15 from file: 108)
1230083 A83-15938

Some characteristics of clear-air turbulence in the middle stratosphere

BARAT, J. (CNRS, Service d'Aeronomie, Verrieres le Buisson, Essonne, France)

Journal of the Atmospheric Sciences, vol. 39, Nov. 1982, p. 2553-2564.

Publication Date: Nov. 1982 25 Refs.

Language: English

Country of Origin: France Country of Publication: United States

Document Type: JOURNAL ARTICLE

Documents available from AIAA Technical Library

Journal Announcement: IAA8304

Analysis of clear-air turbulence measurements obtained from highly sensitive balloon-borne instrumentation is presented. Emphasis is placed on the structure of the turbulent velocity field in the inertial range. Regions of weak turbulence are found to be associated with low Richardson numbers and negative temperature gradients. Measurements of the turbulent energy intensity are presented. The extension of the inertial range is found to be consistent with theoretical values in the case of stably stratified flow. The turbulence intensity varies significantly over a two-hour time interval. An important result is the observational evidence for a $2/3$ law behavior in the structure function at scales where the turbulent velocity field cannot be isotropic: this behavior cannot be explained by a two-dimensional turbulence field. ((Author))

17 (Item 17 from file: 108)
1223702 N83-36608

Investigation of shear-induced turbulence by MST (Mesosphere-Stratosphere

-Troposphere radar)

Final Report, 1 Oct. 1980 - 30 Sep. 1982

ROMICK, G. J.; JAYAWEEA, K.; SMITH, S. A.

Alaska Univ., Fairbanks. Geophysical Inst.

Publication Date: Sep. 1982 32P.

Report No.: AD-A129203; AFOSR-83-0437TR

Contract No.: AF-AFOSR-0286-80; AF PROJ. 2310

Language: English

Country of Origin: United States Country of Publication: United States

Document Type: REPORT

Documents available from AIAA Technical Library

Other Availability: NTIS HC A03/MF A01

Journal Announcement: STAR8324

Wind speed and $C_{sub N}$ squared measurements made with the Poker Flat, Alaska MST radar are used to study the development of clear air turbulence (CAT) near the tropopause. Arguments and observations that indicate $C_{sub N}$ squared is proportional to the intensity of turbulence are presented. The relationship between wind shear and turbulence is examined using time-lagged cross correlations of measured shears and $C_{sub N}$ squared time series. From analysis of data taken with spatial resolutions of 2200 m and 750 m, it is found that the correlation improves as the time and spatial resolutions of the measurements improve. The implications for forecasting CAT are discussed, based on the correlation results and a comparison of radar data with National Weather Service CAT forecasts. (Author (GRA))

Source of Abstract/Subfile: DTIC

29 (Item 29 from file: 108)

0918196 N78-17634

Stratospheric turbulence analysis

Final Report, 1 Jan. - 31 Aug. 1977

CRANE, R. K.

Environmental Research and Technology, Inc., Concord, Mass.

Publication Date: Sep. 1977 149P.

Report No.: AD-A047740; AFGL-TR-77-0207

Contract No.: F19628-77-C-0059

Language: English

Country of Origin: United States Country of Publication: United States

Document Type: REPORT

Documents available from AIAA Technical Library

Other Availability: NTIS HC A07/MF A01

Journal Announcement: STAR7808

A model was developed to combine radiosonde observations with ultrasensitive well-calibrated radar measurements of clear air turbulence to provide estimates of two eddy parameters, the eddy dissipation rate and the eddy heat diffusion coefficient. The eddy parameters were obtained as volume averages over 1 km thick layers and time averages over several hours. The model was tested using simultaneously obtained radar

measurements and pilot reports of turbulence intensity from a U-2 aircraft.

The model was also shown to be consistent with other reported radar and

aircraft measurements. (Author (GRA))

Source of Abstract/Subfile: DTIC

30 (Item 30 from file: 108)

0869828 A78-13111

**A comparison of estimated and directly measured
turbulent heat fluxes in
the lower stratosphere**

HECK, W. (NASA, Goddard Institute for Space Studies, New York, N.Y.)

National Aeronautics and Space Administration. Goddard Inst. for

Space

Studies, New York.

Monthly Weather Review, vol. 105, Oct. 1977, p. 1337-1340

Publication Date: Oct. 1977

Contract No.: NSF CD-73-00215-A01

Language: English

Country of Origin: United States Country of Publication: United
States

Document Type: JOURNAL ARTICLE

Documents available from AIAA Technical Library

Journal Announcement: IAA7802

The contribution of small-scale motions to the vertical heat flux in
the

lower stratosphere is determined from wind and temperature
fluctuation

statistics obtained during the High Altitude Clear Air Turbulence
investigation. Analysis of the cospectra suggests a horizontal
wavelength

of 3 km as the appropriate long-wave cutoff of small-scale motion.

With

this scale restriction, the measured vertical heat fluxes are in good
agreement with the values of heat flux estimated by Lilly et al.

(1974)

from the kinetic energy dissipation rate. Hence, the hypothesis of Lilly
et

al. for estimating heat flux from the dissipation rate is considered to
be

reliable. It follows that, in the lower stratosphere, subsynoptic
vertical

transport is small compared to large-scale transport. ((Author))

45 (Item 45 from file: 108)

0674418 N74-11274

**Turbulence near the tropopause in the presence of
mountain waves**

BULDOVSKIY, G. S.

Air Force Systems Command, Wright-Patterson AFB, Ohio. Foreign
Technology
Div.

Publication Date: Aug. 1973 18P.
Translation Note: Transl. into ENGLISH from Analiz Meteorol. Uslovii
dlya

Aviatsii (USSR), no. 95, 1972 p 17-26

Report No.: AD-766577; FTD-MT-24-744-73

Language: English

Country of Origin: U.S.S.R. Country of Publication: United States

Document Type: JOURNAL ARTICLE; TRANSLATION

Documents available from AIAA Technical Library

Other Availability: NTIS

Journal Announcement: STAR7402

Investigation of the conditions for the development of turbulence
near
the tropopause, especially above a mountainous region, has great
current
significance in connection with the forthcoming flights of
supersonic
passenger aircraft. Near the tropopause there will be a transition zone
to
supersonic speed. The report discusses research on the conditions
of
turbulence near the tropopause above mountainous regions and
simultaneous
distribution of turbulence in the troposphere and the lower
stratosphere. (

GRA)

Source of Abstract/Subfile: DTIC

47 (Item 47 from file: 108)

0636015 N73-33522

**Analysis of meteorological conditions for aviation
(Meteorological and**

**weather effects on aircraft landings and flights along air lanes and
stratospheric wind effects on supersonic transports)**

ABRAMOVICH, K. G., ed.

Joint Publications Research Service, Arlington, Va.

Publication Date: Sep. 1973 69P.

Translation Note: Transl. into ENGLISH of the publ. "Analiz
Meteorologicheskikh Usloviy dlya Aviatsii" Leningrad,
Gidrometeoizdat,

1972 63 p

Report No.: JPRS-60114

Language: English

Country of Origin: U.S.S.R. Country of Publication: United States

Document Type: BOOK; TRANSLATION

Documents available from AIAA Technical Library

Other Availability: NTIS

Journal Announcement: STAR7324

Results are presented of studies conducted on weather phenomena
which can
limit aircraft landings and flights along air lanes. The effects of the
spatial variability of the wind in the stratosphere on the accuracy of
maintaining a flight trajectory by a supersonic transport at a given
altitude are also discussed.

52 (Item 52 from file: 108)
0571884 N72-28304

**Fine structure of the middle and high stratosphere.
Detection of clear**

air turbulence. Application to flights envisaged from supersonic transport aircraft (Wind, temperature, and clear air turbulence in middle and upper stratosphere)

BARBE, G. D.; et al.

National Lending Library for Science and Technology, Boston Spa (England).

Publication Date: 1972 19P.

Translation Note: Transl. into ENGLISH from the publ.

"French/American

Meteorological Societies Joint Meeting" Paris, 1971

Report No.: NLL-M-22438-(5828.4F)

Language: English

Country of Origin: France Country of Publication: United Kingdom

Document Type: CONFERENCE PAPER; TRANSLATION

Documents available from AIAA Technical Library

Other Availability: Natl. Lending Library, Boston Spa, Engl.: 2 NLL photocopy coupons

Journal Announcement: STAR7219

Wind and fine scale temperature soundings were carried out under a variety of experimental conditions. Clear air turbulence measurements

observations were made using Canberra and Concorde aircraft. The results

are presented in the form of curves giving the distributions as a function

of altitude, height, wind speed, and temperature. (K.P.D.)

Source of Abstract/Subfile: NASA STIF

FORECASTS

98 (Item 2 from file: 6)
1084815 NTIS Accession Number: AD-A144 854/7
Clear Air Turbulence Forecasting Techniques
(Technical note)
Lee, D. R. ; Stull, R. S. ; Irvine, W. S.
Air Force Global Weather Central, Offutt AFB, NE.
Corp. Source Codes: 024886000; 403677
Sponsor: Shared Bibliographic Input.
Report No.: AFGWC-TN-79-001(REV); SBI-AD-E850 734
Feb 84 84p
Languages: English
Journal Announcement: GRAI8425
Revision of report dated Dec 79, AD-A083 099.
NTIS Prices: PC A05/MF A01
Country of Publication: United States

This technical note is a compilation of the latest clear air turbulence(CAT) forecasting techniques used by AFGWC forecasters. It is a comprehensive treatment of a complex and unique forecasting subject. The methods are relatively easy to follow and are a step-by-step approach to forecasting this weather phenomenon. This document replaces AFGWC Tech Memo 70-7 Turbulence Forecasting Procedures , 15 Dec 1970. Over the past 15 years the automated CAT routines have been totally replaced. Also, synoptic rules of thumb and model relationships are now better understood and documented.

104 (Item 8 from file: 6)
220989 NTIS Accession Number: AD-818 985
Numerical Forecasting of Clear Air Turbulence
(Masters thesis)
Ettel, Michael Joseph ; Morgan, William Allen
Naval Postgraduate School, Monterey, Calif.
Corp. Source Codes: 251450
Jun 67 172p
Document Type: Thesis
Journal Announcement: GRAI7113
Distribution Limitation now Removed.
NTIS Prices: PC A08 MF A01

There is much disagreement as to (1) what causes clear air turbulence (turbulence which is not in or near convective clouds and is above 15,000 feet in altitude) and (2) which meteorological parameters can be used to detect and forecast its occurrence. The approach to this problem has been to relate not one parameter to clear air turbulence but various parameters. By summing these parameters areas can be defined where there is a high probability of encountering clear air turbulence. Each parameter has been based on a statistical study which found a relationship with clear air turbulence. The parameters used were horizontal and vertical shear, curvature, kinetic energy and their derivatives. The numerical forecasting program proposed here can be extended to the stratosphere when more reliable height and temperature fields are available. (Author)

110 (Item 2 from file: 2)01662673 INSPEC Abstract Number: A81036039

Title: Probability forecasts of *clear*-air* *turbulence* based on numerical model output

Author(s): Dutton, M.J.O.

Author Affiliation: Meteorological Office, Bracknell, UK

Journal: Meteorological Magazine vol.109, no.1299 p.293-306

Publication Date: Oct. 1980 **Country of Publication:** UK

CODEN: MTMGA5 **ISSN:** 0026-1149

Language: English **Document Type:** Journal Paper (JP)

Treatment: General, Review (G); Experimental (X)

Abstract: During the 1976 Turbulence Survey, pilots' reports of clear-air turbulence (CAT) from about 4500 flights over the North Atlantic and north-west Europe were collected, the main aim being to assess the potential, as predictors of CAT, of various synoptic-scale meteorological indices computed by the operational 10-level model. Analysis of the pilot's reports of CAT versus various meteorological indices computed by the 10-level model (rectangle area) indicates that an index combining the predictive abilities of vertical and horizontal wind shear can significantly out-perform conventional CAT forecasts. In addition it is thought that forecasts of CAT must be stated in terms of probability (e.g. per 100 km of flight) if they are to convey the maximum possible information to the user. (11 Refs)

116 (Item 8 from file: 2)

00299314 INSPEC Abstract Number: A71062655

Title: Cloud and synoptic parameters associated with *clear* *air* *turbulence*

Author(s): Ball, J.T.

Issued by: Center Environment & Man Inc., Hartford, CT, USA

Publication Date: Aug. 1970 **Country of Publication:** USA 72 pp.

Report Number: NASA-111778 **Contract Number:** NAS12-699

Availability: NTIS, Springfield, VA 22151, USA

Language: English **Document Type:** Report (RP)

Treatment: Experimental (X)

Abstract: Research was initiated to determine relationships between clear air turbulence (CAT) in the stratosphere and upper troposphere and meteorological variables, circulation features and cloud characteristics. For this purpose, a total of 372 cases of CAT occurrence and nonoccurrence were analyzed using aircraft instrumented reports of CAT in the 45000-70000 ft layer as obtained by the US Air Force in Project HICAT from 1966 through 1968. Light to moderate or more intense CAT occurs frequently when the vertical temperature profile about the level of interest is irregular and includes both strong inversions and layers in which the temperature decreases rapidly with height. Consistent numerical relationships were determined for a number of meteorological variables describing this condition. Implementation of these results for the development of CAT detection instrumentation is discussed. The analysis of circulation features showed that significant stratospheric CAT was associated with large horizontal temperature gradients at upper-level surfaces. Cloud characteristics associated with significant turbulence were cirrus bands and streaks, a well-defined frontal cloud band, transverse wave clouds, and cumulonimbus clouds.

36 (Item 36 from file: 108)
0782171 N76-14711

Relationships between stratospheric clear air turbulence and synoptic meteorological parameters over the western United States between 12-20 km altitude

Final Report

SCOGGINS, J. R.; CLARK, T. L.; POSSIEL, N. C.

Texas A&M Univ., College Station.

Publication Date: Dec. 1975 162P.

Report No.: NASA-CR-143837; H-919

Contract No.: NGR-44-001-081

Language: English

Country of Origin: United States Country of Publication: United States

Document Type: REPORT

Documents available from AIAA Technical Library

Other Availability: NTIS

Journal Announcement: STAR7605

Procedures for forecasting clear air turbulence in the stratosphere over the western United States from rawinsonde data are described and results presented. Approaches taken to relate meteorological parameters to regions of turbulence and nonturbulence encountered by the XB-70 during 46 flights at altitudes between 12-20 km include: empirical probabilities, discriminant function analysis, and mountainwave theory. Results from these techniques were combined into a procedure to forecast regions of clear air turbulence with an accuracy of 70-80 percent. A computer program was developed to provide an objective forecast directly from the rawinsonde sounding data. (Author)

41 (Item 41 from file: 108)
0721529 A75-35415

Meteorological variables versus CAT in the stratosphere - A statistical approach

SCOGGINS, J. R. (Texas A & M University, College Station, Tex.)

In: Conference on Aerospace and Aeronautical Meteorology, 6th, El Paso, Tex., November 12-15, 1974, Preprints. (A75-35351 16-47) Boston, Mass., American Meteorological Society, 1974, p. 339-344.

Publication Date: 1974 20 Refs.

Contract No.: NGR-44-001-081

Language: English

Country of Origin: United States Country of Publication: United States

Document Type: CONFERENCE PAPER

Journal Announcement: IAA7516

Frequency distributions prepared from synoptic meteorological parameters at 300, 200, and 100 mb, associated with turbulent and non-turbulent areas encountered by the XB-70 airplane in the stratosphere (between 12 and 20 km), show that turbulence occurs more frequently than non-turbulence when the parameters exceed certain values. A procedure proposed for forecasting clear-air turbulence on the basis of the number of exceedances of limits of specified variables is verified for two flights of the XB-70 airplane. The procedure gives the geographical location of CAT regions, but further research is required before the altitude of CAT can be specified. (V.P.)

Source of Abstract/Subfile: AIAA/TIS

48 (Item 48 from file: 108)
0618372 N73-15451

Some results from experimental investigations of turbulence in the troposphere and stratosphere (Statistical correlations between clear air turbulence and macrosynoptic processes in troposphere and stratosphere)

PINUS, N. Z.; SHUR, G. N.

Air Force Systems Command, Wright-Patterson AFB, Ohio. Foreign Technology Div.

Publication Date: Sep. 1972 33P.

Translation Note: Transl. into ENGLISH from Beitr. Geophysik (Leipzig), v. 79, no. 5, 1970 p 363-378

Report No.: AD-750514; FTD-HC-23-538-72

Language: English

Country of Origin: Germany, Peoples Democratic Republic of

Country of Publication: United States

Document Type: REPORT; TRANSLATION

Documents available from AIAA Technical Library

Other Availability: NTIS

Journal Announcement: STAR7306

After introductory comments on the significance of turbulence research in terms of modern aviation, the authors investigate the character of turbulence on the scales concerned here. The sources and depressions of turbulent energy as well as the forms of energy spectra are discussed here in connection with various atmospheric conditions. On the basis of aircraft observations, data is presented on the appearance and character of turbulence in the stratosphere and on the level of the tropopause. Finally, the results are given for a statistical investigation of the tie-in between turbulence and macrosynoptic processes, from which a synoptic-statistical method for the prediction of clear-air turbulence is derived. (Author (GRA)

)

Source of Abstract/Subfile: DTIC

53 (Item 53 from file: 108)
0571238 N72-27638

Meteorological assistance for the Concorde trial flights (Weather predictions for Concorde test flights and problems of forecasting stratospheric temperature and clear air turbulence)

CAZALE, H. R.

National Lending Library for Science and Technology, Boston Spa (England).

Publication Date: 1972 17P.

Translation Note: Transl. into ENGLISH from the publ. "'French/American Meteorological Societies' Joint Meeting" Paris, 1971 p 1-19

Report No.: NLL-M-22439-(5828.4F)

Language: English

Country of Origin: France Country of Publication: United Kingdom

Document Type: CONFERENCE PAPER; TRANSLATION

Documents available from AIAA Technical Library

Other Availability: Natl. Lending Library, Boston Spa, Eng.: 2 NLL photocopy coupons

Journal Announcement: STAR7218

The weather predictions for the Concorde test flights are discussed for

the prototype and first subsonic flights in the lower atmospheric layers, the subsonic and transonic flights at altitudes between 500 and 200 mb, and the supersonic flights reaching to 100 mb and at a speed of Mach 2. The problems of predicting clear air turbulence and of predicting temperatures at 100 mb and 70 mb with sufficient fine detail and accuracy are described.

The general conclusion is that meteorological help has played an important role in successive phases of the SST tests, and that increasing meteorological assistance will be requested. (N.E.N.)

Source of Abstract/Subfile: NASA STIF

65 (Item 65 from file: 108)

0467492 A71-23070

Meteorology for the supersonic transport (Supersonic transport air

traffic meteorology, considering high altitude and flight velocities, applications technology satellites for lower stratosphere thunderstorms, clear air turbulence, etc)

/Meteorologie fuer den Ueberschall- Luftverkehr/

PANZRAM, H.

NATURWISSENSCHAFTLICHE RUNDSCHAU, VOL. 24, P. 113-115.

Publication Date: Mar. 1971

Language: German

Country of Origin: Germany, Federal Republic of

Document Type: JOURNAL ARTICLE

Documents available from AIAA Technical Library

Journal Announcement: IAA7109

Source of Abstract/Subfile: AIAA/TIS

67 (Item 67 from file: 108)

0452021 N70-40766

**Cloud and synoptic parameters associated with clear air turbulence
Final**

report (Cloud and synoptic parameters associated with clear air turbulence
)

BALL, J. T.

Center for the Environment and Man, Inc., Hartford, Conn.

Publication Date: Aug. 1970 72P.

Report No.: NASA-CR-111778; CEM-7496-413

Contract No.: NAS12-699

Language: English

Country of Origin: United States Country of Publication: United States

Document Type: REPORT

Documents available from AIAA Technical Library

Other Availability: NTIS

Journal Announcement: STAR7023

75 (Item 75 from file: 108)

0392729 A70-17193

Meteorology and the supersonic transport (Meteorological conditions

effects on SST aircraft flight safety and economics, emphasizing stratospheric information for forecasting)

FINGER, F. G.; MCINTURFF, R. M. /U.S. WEATHER BUREAU, NATIONAL METEOROLOGICAL CENTER, HILLCREST HEIGHTS, MD./.

SCIENCE, VOL. 167, P. 16-25.

Publication Date: Jan. 1970

Language: English

Country of Origin: United States Country of Publication: United States

Document Type: JOURNAL ARTICLE

Documents available from AIAA Technical Library

Journal Announcement: IAA7006

Source of Abstract/Subfile: AIAA/TIS

77 (Item 77 from file: 108)

0381249 N69-36983

Research to determine cloud and synoptic parameters associated with clear

air turbulence Interim report (Clear air turbulence in stratosphere and troposphere)

BALL, J. T.; COOLEY, D. S.

Travelers Research Center, Inc., Hartford, Conn.

Publication Date: Jul. 1969 78P.

Report No.: NASA-CR-86229; REPT-7496-362

Contract No.: NAS12-699

Language: English

Country of Origin: United States Country of Publication: United States

Document Type: REPORT

Documents available from AIAA Technical Library

Other Availability: NTIS

Journal Announcement: STAR6921

82 (Item 82 from file: 108)

0340823 A69-29737

Meteorological conditions for the onset of aircraft bumpiness in the stratosphere (Stratospheric turbulence producing bumpiness up to 18 km developing at levels characterized by abrupt changes in vertical temperature gradients)

Meteorologicheskie uslovia vozniknoveniia boltanki samoletov v stratosfere

BULDOVSKII, G. S.

Place of Publication: LENINGRAD Publisher: GIDROMETEOIZDAT

Publication Date: 1968 13P. 13 Refs.

Publication Note: IN- AVIATION FORECASTING OF THE CLOUD COVER, HIGH-ALTITUDE WIND, AND TURBULENCE <PROGNOZIROVANIE DLIA AVIATSII OBLACHNOSTI, VETRA NA VYSOTAKH I TURBULENTNOSTI>. EDITED BY K. G. ABRAMOVICH. <A69-29734 14-20> /GLAVNOE UPRAVLENIE

GIDROMETEOROLOGICHESKOE

SLUZHBY SSSR, GIDROMETEOROLOGICHESKII NAUCHNO- ISSLEDOVATELSKII TSENTR, TRUDY, NO. 35/, P. 36-48.

Language: Russian

Country of Origin: U.S.S.R.

Document Type: ANALYTIC OF COLLECTED WORK; TRANSLATION

Documents available from AIAA Technical Library

Journal Announcement: IAA6914

83 (Item 83 from file: 108)

0328875 A69-17789

An evaluation of stratospheric CAT forecasts for mid latitudes. (

Stratospheric critical clear atmospheric turbulence at midlatitudes, noting applications to supersonic aircraft design)

POWELL, F. A. /BUREAU OF METEOROLOGY, CENTRAL OFFICE, MELBOURNE, AUSTRALIA/.

AUSTRALIAN METEOROLOGICAL MAGAZINE, VOL. 16, P. 35-46. 6 REFS.

Publication Date: Jun. 1968

Language: English

Country of Origin: Australia Country of Publication: Australia

Document Type: JOURNAL ARTICLE; CONFERENCE PAPER

Documents available from AIAA Technical Library

Journal Announcement: IAA6906

Source of Abstract/Subfile: AIAA/TIS

89 (Item 89 from file: 108)

0244817 N67-28136

Some data on turbulence in the upper troposphere and stratosphere causing

airplane buffeting (Aircraft buffeting due to clear air turbulence in upper troposphere and stratosphere)

PINUS, N. Z.; SHUR, G. N.; VINNICHENKO, N. K.

Joint Publications Research Service, Washington, D. C.

IN ITS METEOROL. AND HYDROL., NO. 11, 1966 21 FEB. 1967 P 35-47 REFS

PRESENTED AT THE SCI. CONF. ON THE FORECASTING OF WIND, TEMP. AND TURBULENCE FOR JET AIRPLANES, MOSCOW, 10-13 NOV. 1965 /SEE N67-28133 15-20/

Publication Date: Feb. 1967

Language: English

Country of Origin: U.S.S.R. Country of Publication: United States

Document Type: REPORT

Journal Announcement: STAR6715

Source of Abstract/Subfile: NASA STIF

93 (Item 93 from file: 108)

0047629 A64-20492

Progress in clear-air turbulence research and forecasting. (Topcat project to investigate and forecast clear air turbulence for sst operations)

REITER, E. R. /COLORADO STATE U., FORT COLLINS, COLO./.

American Inst. of Aeronautics and Astronautics, New York.

AMERICAN INST. OF AERONAUTICS AND ASTRONAUTICS, ANNUAL MEETING, 1ST, WASHINGTON, D.C., JUN. 29- JUL. 2, 1964, PAPER 64-311. 8 P. 26 REFS.

Publication Date: 1964

Report No.: AIAA PAPER 64-311

Language: English

Document Type: REPORT; CONFERENCE PAPER

Documents available from AIAA Technical Library

Journal Announcement: IAA6416

94 (Item 94 from file: 108)

0045461 A64-18324

Cat and scat. (Stratospheric clear air turbulence prediction for supersonic commercial air transport)

REITER, E. R. /COLORADO STATE U., FORT COLLINS, COLO./.

ASTRONAUTICS AND AERONAUTICS, VOL. 2, MAY 1964, P. 60-65. 46 REFS.

Publication Date: 1964
Language: English
Document Type: REPORT
Documents available from AIAA Technical Library
Journal Announcement: IAA6413

